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BC # 545234

MODEL
SP 2288
~~H 730769-1~~
Instruction Manual
AC RATIO MEASURING SYSTEM

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RATIO MEASUREMENTS

AUGUST 1967

MODEL

SP 2288

~~H-730969-2288~~

Instruction Manual

AC RATIO MEASURING SYSTEM

SERIAL NUMBER:_____

PART NUMBER: 82339

TABLE OF CONTENTS

INTRODUCTION
ESI MODEL 791 INSTRUCTION MANUAL
ESI MODEL 1071 INSTRUCTION MANUAL
ESI MODEL RA79 INSTRUCTION MANUAL
ESI MODEL 874 INSTRUCTION MANUAL
ESI MODEL DT72 INSTRUCTION MANUAL
ESI MODEL 861 INSTRUCTION MANUAL

INTRODUCTION

ESI Model SP 2288 AC Ratio Measuring System is a combination of ESI Models 791 and 1071 AC Ratio Measuring Systems. Operation of the systems is described in the manuals for these systems. Interconnection of the system is shown in the following diagram.

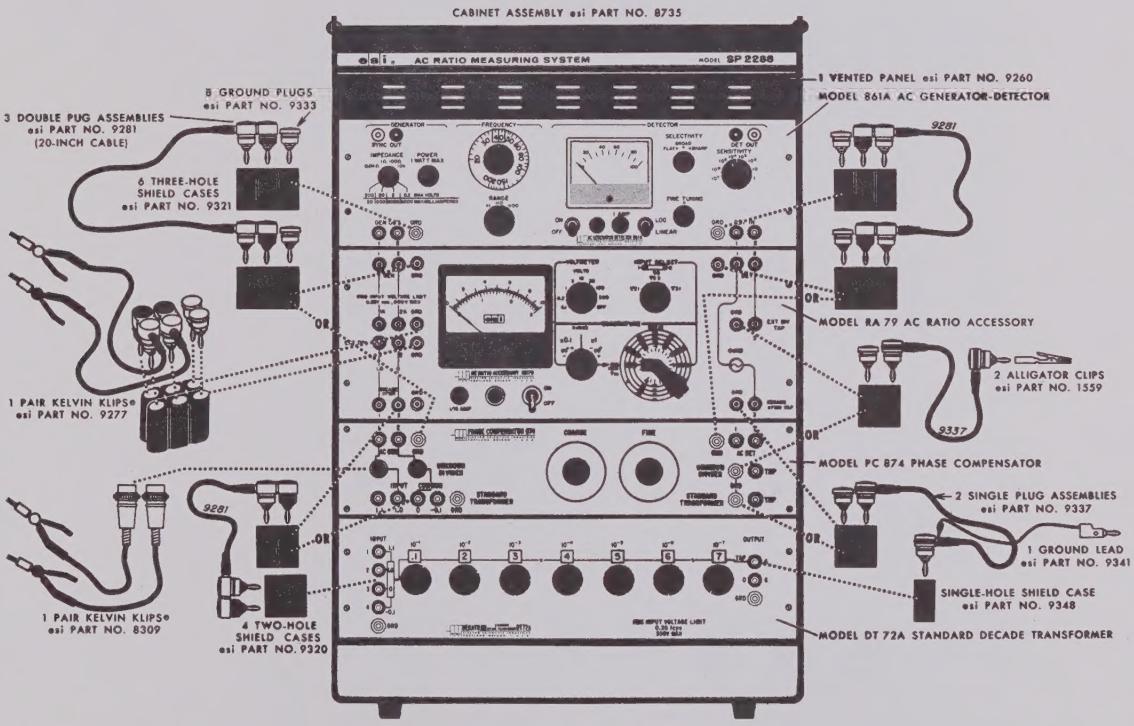
CABINET ASSEMBLY esi PART NO. 8735
esi AC RATIO MEASURING SYSTEM
MODEL SP 2288
8 GROUND PLUGS esi PART NO. 9333
3 DOUBLE PUG ASSEMBLIES esi PART NO. 9281 (20-INCH CABLE)
6 THREE-HOLE SHIELD CASES esi PART NO. 9321
1 PAIR KELVIN KLIPS esi PART NO. 9277
1 PAIR KELVIN KLIPS esi PART NO. 8309
4 TWO-HOLE SHIELD CASES esi PART NO. 9320
1 VENTED PANEL esi PART NO. 9260
MODEL 861A AC GENERATOR-DETECTOR
9281
MODEL RA 79 AC RATIO ACCESSORY
2 ALLIGATOR CLIPS esi PART NO. 1559
9337
MODEL PC 874 PHASE COMPENSATOR
2 SINGLE PLUG ASSEMBLIES esi PART NO. 9337
1 GROUND LEAD esi PART NO. 9341
SINGLE-HOLE SHIELD CASE esi PART NO. 9348
MODEL DT 72A STANDARD DECADE TRANSFORMER
OR

Figure 1. Interconnections

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RATIO
MEASUREMENTS

DECEMBER 1966
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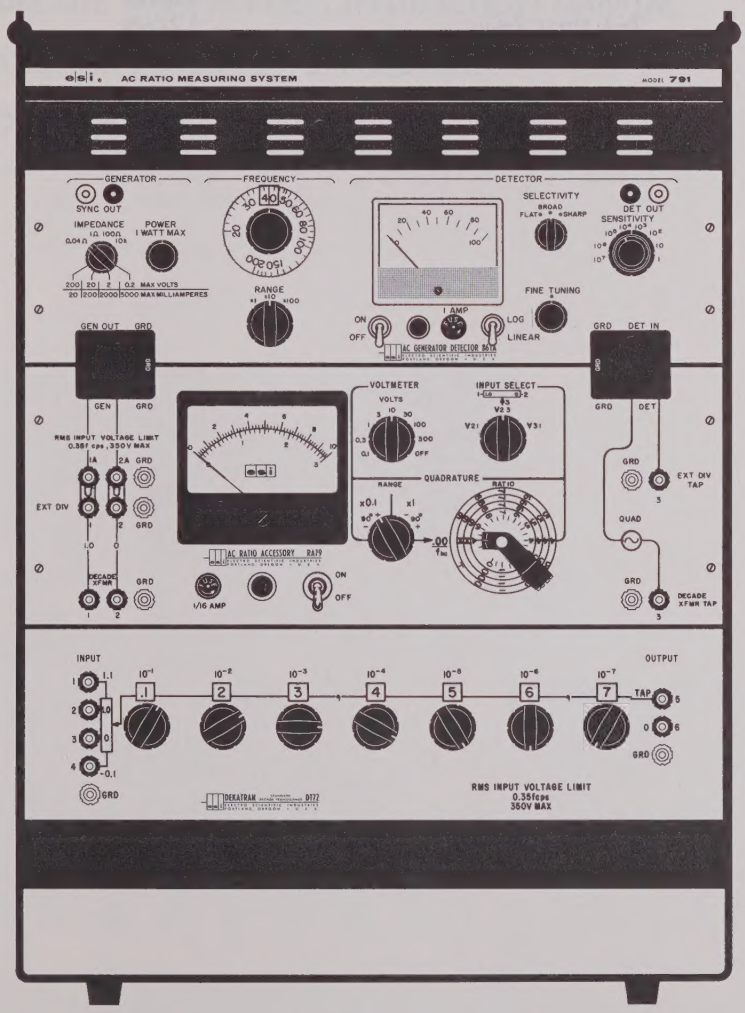
MODEL
791

Instruction Manual

AC RATIO MEASURING SYSTEM



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SERIAL NUMBER:_____

PART NUMBER: 8762

The following table lists the most recent revision of each page at the present printing:

PAGES	DATE
Title	12/66
A	12/66
i and ii	12/66
1-1	12/66
2-1 thru 2-3	12/66
3-1	12/66

TABLE OF CONTENTS

MODEL 791 AC RATIO MEASURING SYSTEM

I. INTRODUCTION 1-1

II. SYSTEM INDEX 2-1

III. LIST OF ACCESSORIES 3-1

MODEL DT72A DEKATRAN DECADE TRANSFORMER, INSTRUCTION MANUAL

MODEL RA79 AC RATIO ACCESSORY, INSTRUCTION MANUAL

MODEL 861A AC GENERATOR-DETECTOR, INSTRUCTION MANUAL

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DEKAVIDER® Decade Voltage Divider
KELVIN KLAMPS® Four-terminal Clamps
KELVIN KLIPS® Four-terminal Clips
PORTAMETRIC® Portable Measuring Instrument
PVB® Potentiometric Voltmeter Bridge

SECTION I

INTRODUCTION

ESI Model 791 AC Ratio Measuring System consists of the ESI Model DT 72A Standard Decade Transformer, the ESI Model 861A AC Generator-Detector, and the ESI Model RA 79 AC Ratio Accessory.

Interconnection of the units is shown in Figures 1 and 2. Instructions for operating and calibrating the system are described in the manuals for the individual instruments, especially the manual for the Model RA 79 AC Ratio Accessory.

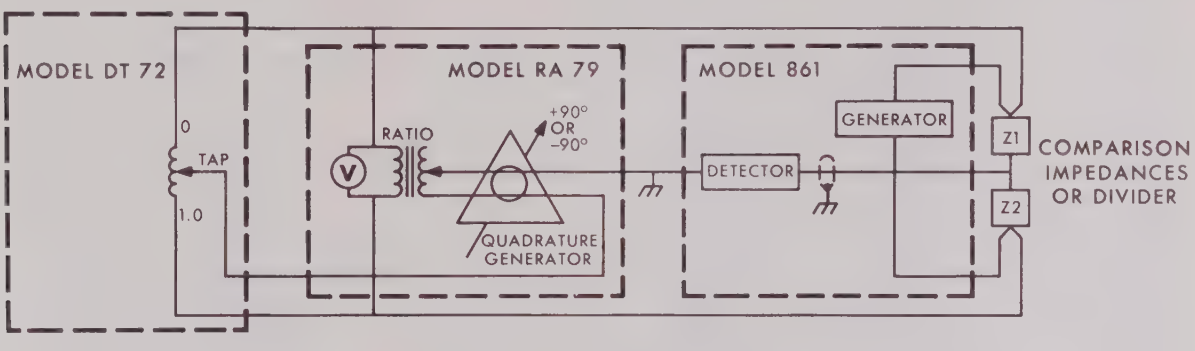

Figure 1. Block Diagram

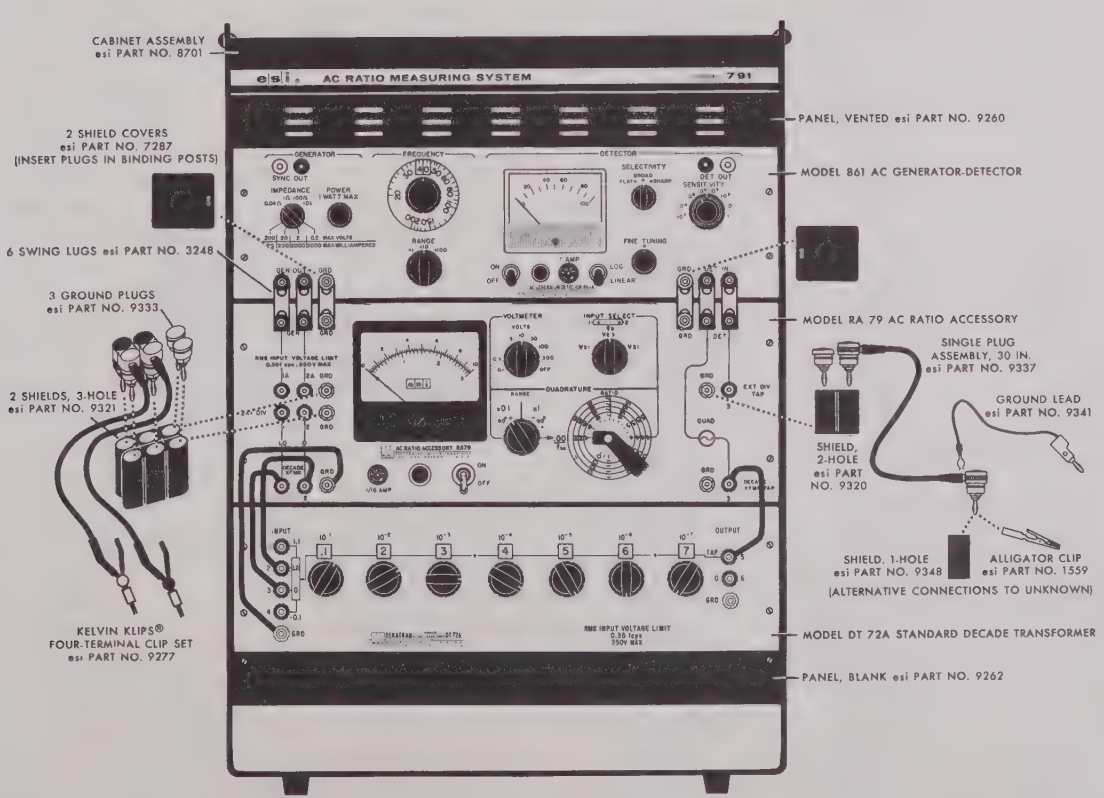

Figure 2. Interconnections

SECTION II

SYSTEM INDEX

The following index is in alphabetical order by subject of all subjects in the instruction manuals of the instruments in the Model 791 AC Ratio Measuring System

SUBJECT	PAGE	PARAGRAPH	MODEL
Adjustments, Trimmer Resistor	4.1-4	4.1.6	861A
Ammeter Calibration	2.2-1	2.2	DT 72A
Amplitude Response Curves	3.4-4	3.4.4	861A
Applications	1.2-1	1.2	RA 79
Auxiliary Equipment	1.4-1	1.4	RA 79
Bridge Connections	2.2-1	2.2	861A
Calibration, Ammeter	2.2-1	2.2	DT 72A
Calibration Procedure	2.3-3	2.3.1	RA 79
Calibration, Voltage Divider	2.3-1	2.3	DT 72A
Calibration, Voltage Divider	2.4-1	2.4	RA 79
Calibration, Voltmeter	2.1-1	2.1	DT 72A
Calibration, Voltmeter	4.1-1	4.1	RA 79
Capacitance Comparison	2.5-5	2.5.1	DT 72A
Circuit Design	3.3-1	3.3	RA 79
Circuit Description, Detector	3.1-1	3.1	861A
Circuit Description, Generator	3.2-1	3.2	861A
Circuit Diagram	4.2-1	4.2	RA 79
Circuit Diagram	4.2-1	4.2	861A
Cleaning and Lubrications	4.1-2	4.1.3	DT 72A
Comparison, Capacitance	2.5-5	2.5.1	DT 72A
Comparison, Impedance	2.5-1	2.5	DT 72A
Comparisons, Impedance	2.5-1	2.5	RA 79
Connections, Bridge	2.2-1	2.2	861A
Connections, Decade Transformer	2.2-1	2.2	RA 79
Connections, External Instruments	2.4-1	2.4	861A
Connections, Generator-Detector	2.1-2	2.1	RA 79
Connections, Voltage Divider Calibration	2.3-1	2.3	861A
Corrections, Magnitude	2.3-7	2.3.2	RA 79
Corrections, Phase	2.3-1	2.3.1	RA 79
Corrections, System	2.3-1	2.3	RA 79
Cover Removal	4.1-1	4.1.2	861A
Decade Transformer Connections	2.2-1	2.2	RA 79
Description	1.1-1	1.1	DT 72A
Description	1.1-1	1.1	RA 79
Description	1.1-1	1.1	861A
Design Features	1.2-1	1.2	DT 72A
Detector Circuit Description	3.1-1	3.1	861A
Detector Specifications	1.2-1	1.2.2	861A
Detector-Generator Connections	2.1-2	2.1	RA 79
Diagram, Schematic, Circuit	4.2-1	4.2	RA 79
Diagrams, Circuit, Schematic	4.2-1	4.2	861A
Divider Calibration, Theory	3.1-1	3.1	RA 79
Dust Cover, Removal	4.1-1	4.1.2	DT 72A

SUBJECT	PAGE	PARAGRAPH	MODEL
Elliptical Cro Patterns	2.4-1	2.4.2	861A
Error, Sources of	3.1-1	3.1	DT 72A
External Instrument Connections	2.4-1	2.4	861A
Features, Design	1.2-1	1.2	DT 72A
Frequency Adjustment, High-Accuracy	2.4-4	2.4.5	861A
Frequency Response Curves	3.4-1	3.4.1	861A
Generator Circuit Description	3.2-1	3.2	861A
Generator Output Curves	3.4-5	3.4.5	861A
Generator Specifications	1.2-1	1.2.1	861A
Generator-Detector Connections	2.1-2	2.1	RA 79
Grounding, Precautions	2.6-1	2.6.3	861A
High-Gain Amplifier Applications	2.5-1	2.5.1	861A
Impedance Comparison Measurements	2.5-1	2.5	DT 72A
Impedance Comparisons	2.5-1	2.5	RA 79
Impedance Comparisons, Theory	3.2-1	3.2	RA 79
Inspection, Visual	4.1-1	4.1.1	DT 72A
Lissajous Cro Patterns	2.4-1	2.4.2	861A
Loading Effects	3.2-1	3.2	DT 72A
Lubrication and Cleaning	4.1-2	4.1.3	DT 72A
Magnitude Corrections	2.3-7	2.3.2	RA 79
Maintenance	4.1-1	4.1--4.2	RA 79
Maintenance, Periodic	4.1-1	4.1	DT 72A
Noise Power Curve	3.4-3	3.4.3	861A
Noise Voltage and Current Curves	3.4-2	3.4.2	861A
Operating Instructions	2.1-2	2.1--2.5	RA 79
Operating Performance Curves	3.4-1	3.4	861A
Operating Precautions	2.6-1	2.6	861A
Operating Procedure	2.1-1	2.1	861A
Operation	2-1	2.1--2.5	DT 72A
Oscilloscope, Lissajous Patterns	2.4-1	2.4.2	861A
Oscilloscope Patterns, Sinusoidal	2.4-2	2.4.3	861A
Output Jacks, External Instruments	2.4-1	2.4.1	861A
Parts List	5-1	5	DT 72A
Parts List	5-1		RA 79
Parts List	4.3-1	4.3	861A
Performance Curves	3.4-1	3.4	861A
Phase Corrections	2.3-1	2.3.1	RA 79
Physical Specifications	1.2-2	1.2.3	861A
Precautions, Operating	2.6-1	2.6	861A
Printed Circuit Repair	4.1-3	4.1.5	861A
Remote Meter Connection	2.4-2	2.4.4	861A
Removing The Dust Cover	4.1-1	4.1.2	DT 72A
Repair of Printed Circuit Assemblies	4.1-3	4.1.5	861A
Replacing The Dust Cover	4.1-2	4.1.4	DT 72A
Schematic Diagram	4.2-1	4.2	RA 79
Schematic Diagrams	4.2-1	4.2	861A
Shielding, Precautions	2.6-1	2.6.2	861A
Sinusoidal Cro Patterns	2.4-2	2.4.3	861A
Sources of Error	3.1-1	3.1	DT 72A
Specifications	1.3-1	1.3	RA 79

SUBJECT	PAGE	PARAGRAPH	MODEL
Specifications	1.2-1	1.2	861A
Specifications, General	1.3-3	1.3	DT 72A
Specifications, Input Impedance	1.3-1	1.3	DT 72A
Specifications, Linearity and Phase Shift	1.3-1	1.3	DT 72A
Specifications, Output Impedance	1.3-2	1.3	DT 72A
Specifications, Output Loading	1.3-2	1.3	DT 72A
System Corrections	2.3-1	2.3	RA 79
Test Voltages	4.2-1	4.2	RA 79
Theory	3.1-1	3.1--3.2	DT 72A
Theory, Divider Calibration	3.1-1	3.1	RA 79
Theory, Impedance Comparisons	3.2-1	3.2	RA 79
Transformer, Decade, Connections	2.2-1	2.2	RA 79
Trimmer Resistor Adjustments	4.1-4	4.1.6	861A
Troubleshooting	4.1-1	4.1	861A
Tube Replacement	4.1-1	4.1.3	861A
Tuning Network, Theory	3.3-1	3.3	861A
Visual Inspection	4.1-1	4.1.1	DT 72A
Voltage Divider Calibration	2.3-1	2.3	DT 72A
Voltage Divider Calibration	2.4-1	2.4	RA 79
Voltage Divider Calibration Connections	2.3-1	2.3	861A
Voltage Measurements	4.1-2	4.1.4	861A
Voltmeter Calibration	2.1-1	2.1	DT 72A
Voltmeter Calibration	4.1-1	4.1	RA 79
Wave Analyzer Applications	2.5-1	2.5.2	861A

SECTION III

LIST OF ACCESSORIES

The following list of items are in the interconnection kit (ESI Part No. 1543) for the Model 791 AC Ratio Measuring System. All items listed are manufactured and/or supplied by Electro Scientific Industries, Inc., 13900 N.W. Science Park Drive, Portland, Oregon and may be ordered from the factory.

The Federal Supply Code for Manufacturers (FSC) for Electro Scientific Industries is 11837.

When ordering parts, please include the following information:

Name and model number of the system (Model 791 AC Ratio Measuring System)

ESI Part Number

Description of Part

DESCRIPTION	PART NO.	QTY USED
Cable, Single Plug 30-inch	9337	1
Clip	1559	1
Double Plug With Kelvin Klip 30-inch	9277	1 set
Ground Lead	9341	1
Ground Plug	9333	3
Instruction Manual 791	8762	1
Jumper Set	6158	1
Jumper Set	6162	1
Jumper Set	6163	1
Jumper Set	6166	1
Shield, 1-Hole	9348	1
Shield, 2-Hole	9320	1
Shield, 3-Hole	9321	2
Swing Lug	3248	6

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BRIDGES
AND
ACCESSORIES

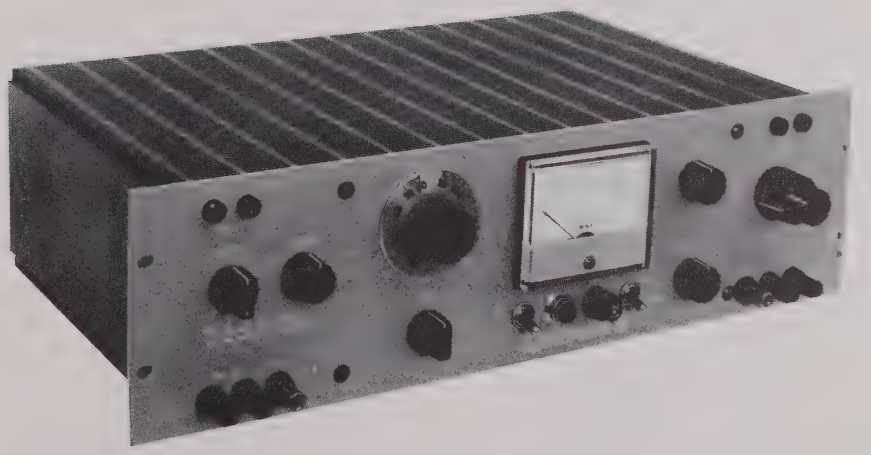
JULY 1964
REPLACES JANUARY 1963

MODEL

861A

Instruction Manual

GENERATOR
DETECTOR
AC



SERIAL NUMBER:_____

PART NUMBER: 9103

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TABLE OF CONTENTS

I DESCRIPTION AND SPECIFICATIONS

1.1 DESCRIPTION
1.2 SPECIFICATIONS

II OPERATING INSTRUCTIONS

2.1 GENERAL OPERATING PROCEDURE
2.2 BRIDGE CONNECTIONS
2.3 CONNECTIONS FOR VOLTAGE DIVIDER CALIBRATION
2.4 CONNECTIONS TO EXTERNAL INSTRUMENTS
2.5 MISCELLANEOUS APPLICATIONS
2.6 OPERATING PRECAUTIONS

III THEORY OF OPERATION

3.1 DETECTOR CIRCUIT DESCRIPTION
3.2 GENERATOR CIRCUIT DESCRIPTION
3.3 TUNING NETWORK

IV MAINTENANCE

4.1 TROUBLE SHOOTING
4.2 CIRCUIT DIAGRAM
4.3 PARTS LIST

1.1 DESCRIPTION

The 861A AC GENERATOR-DETECTOR consists of a variable frequency generator and low noise, high gain, tuned detector. It is designed especially for use in performing bridge measurements with state-of-the-art precision.

Among the many unique design features which contribute to the operating convenience and accuracy of this unit are:

CONTINUOUS SINGLE-CONTROL TUNING OF BOTH THE GENERATOR AND THE DETECTOR eliminates the possibility of inadvertently mistuning the detector with a consequent large loss of sensitivity.

POWER-LIMITED GENERATOR OUTPUT prevents accidental damage to the external circuit.

REGULATED GENERATOR AND DETECTOR POWER SUPPLIES increase stability with line voltage fluctuations.

VARIABLE GENERATOR OUTPUT IMPEDANCE permits optimum matching to a wide range of impedances for maximum system sensitivity.

GUARDED GENERATOR OUTPUT TRANSFORMER minimizes stray capacitances.

GENERATOR SYNC OUT TERMINALS supply a signal of generator frequency which is independent of output control setting or generator loading. The signal may be used to synchronize a null indicating oscilloscope or phase sensitive voltmeter or for measurement of the generator frequency.

TWO TUNED DETECTOR STAGES give maximum rejection of harmonics and other spurious frequencies.

MULTISTAGE DETECTOR LIMITING permits rapid recovery from large overloads for fastest bridge balancing.

SELECTABLE 60 db COMPRESSION OF METER READING minimizes changes in gain setting.

DET OUT TERMINALS make the detector signal available for an external meter or oscilloscope.

VARIABLE DETECTOR SELECTIVITY permits optimum balance between detector response time and spurious frequency signal rejection.

1.2 SPECIFICATIONS

1.2.1 GENERATOR

Frequency:	Continuously variable in three ranges from 20 cps to 20,000 cps.
Output Voltage:	Four ranges; 0-0.2V, 0-2V, 0-20V, and 0-200V, all with less than 2% distortion. Maximum power into a matched load is one watt.
Output Circuit:	Four output impedances; 0.04Ω, 1Ω, 100Ω, and 10KΩ. Guarded transformer with less than 50 pf guard capacitance to ground, and less than 4 pf from guarded terminal to ground.

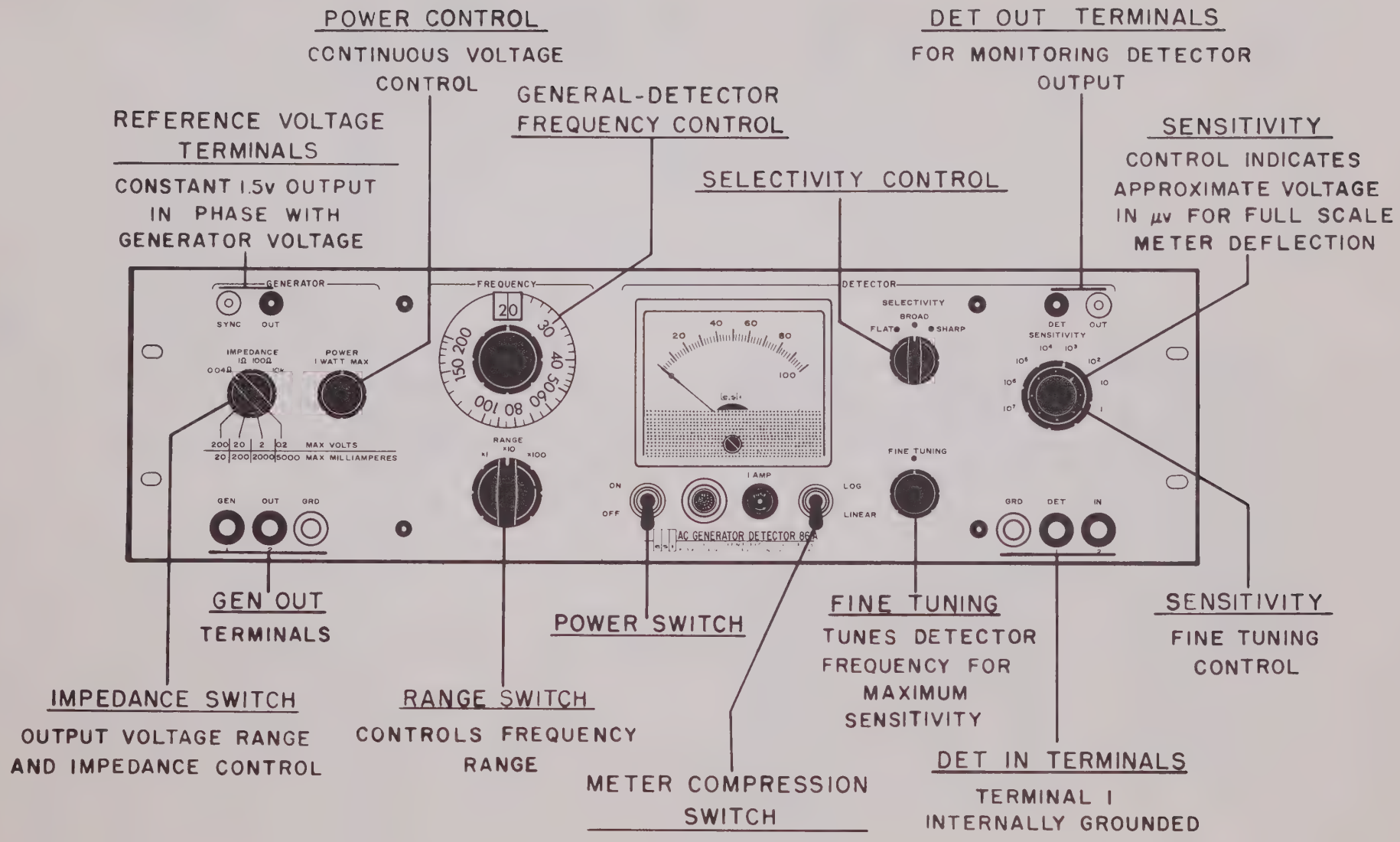
1.2.2 DETECTOR

Frequency:	Continuously variable in three ranges from 20 cps to 20,000 cps. Tuned with the generator.
Sensitivity:	Full scale deflection with one microvolt or less input signal.
Noise:	Maximum short circuit input noise voltage at 1 kc is 0.25 microvolts RMS. Typical short circuit noise is less than $\left[0.1 + 0.1\sqrt{f_{kc}}\right]$ microvolts RMS where f_{kc} is the frequency to which the detector is tuned. Maximum 1 kc open circuit noise current is 2.5 picoamperes. Typical open circuit noise current is less than $\left[1 + 0.5\ f_{kc}\right]$ picoamperes.
Input Impedance:	Approximately one megohm shunted by 80 picofarads on the most sensitive range. Capacitance reduced to less than 20 picofarads on other ranges.

Maximum Input Voltage:	200 volts RMS AC or 400 volts DC.
Indication:	3-1/2 inch rectangular panel meter. Linear mode sensitivity can be adjusted for full scale deflection with any input voltage between 1 microvolt and 100 volts. Logarithmic scale extends the range three decades beyond the linear full scale.
Selectivity:	Three positions available. Typical rejection in sharp position is 40-45 db for half and double frequency points, 50-55 db for one third and three times frequency. Ultimate high and low frequency rejection in excess of 70 db. Typical 3 db bandwidth is 7% of nominal frequency.
Overload Recovery:	Typical 1 kc overload recovery time is less than 0.1 seconds for 10^5 overload. Amplifier overloads smoothly with no foldback (downward deflection) for any overload condition.

1.2.3 PHYSICAL

Height:	5.25 inches.
Width:	19 inches.
Depth:	11.2 inches.
Weight:	22 lbs. net 32 lbs. shipping
Power Requirements:	115/230 ±10% volts AC, 50-400 cps, 0.6 amp.


POWER CONTROL
CONTINUOUS VOLTAGE CONTROL
DET OUT TERMINALS
FOR MONITORING DETECTOR OUTPUT
GENERAL-DETECTOR FREQUENCY CONTROL
REFERENCE VOLTAGE TERMINALS
CONSTANT 1.5v OUTPUT IN PHASE WITH GENERATOR VOLTAGE
SELECTIVITY CONTROL
SENSITIVITY
CONTROL INDICATES APPROXIMATE VOLTAGE IN μv FOR FULL SCALE METER DEFLECTION
GENERATOR
SYNC
OUT
IMPEDANCE
POWER
1 WATT MAX
MAX VOLTS
MAX MILLIAMPERES
FREQUENCY
RANGE
GEN
OUT
GRD
ON
OFF
1 AMP
LOG
LINEAR
AC GENERATOR DETECTOR 86A
DETECTOR
SELECTIVITY
BROAD
FLAT
SHARP
DET SENSITIVITY
DET
OUT
FINE TUNING
GRD
DET
IN
GEN OUT TERMINALS
POWER SWITCH
FINE TUNING
TUNES DETECTOR FREQUENCY FOR MAXIMUM SENSITIVITY
SENSITIVITY
FINE TUNING CONTROL
IMPEDANCE SWITCH
OUTPUT VOLTAGE RANGE AND IMPEDANCE CONTROL
RANGE SWITCH
CONTROLS FREQUENCY RANGE
METER COMPRESSION SWITCH
DET IN TERMINALS
TERMINAL 1 INTERNALLY GROUNDED

2.1 GENERAL OPERATING PROCEDURE

The following control settings should be used as a guide in the initial operation of the 861A GENERATOR-DETECTOR. Instructions for specific applications will be found in Sections 2.2 through 2.6.

Turn the AC line switch on.

To achieve maximum stability, allow 15 minutes for warmup.

Set the output IMPEDANCE switch to the desired position.

The optimum output impedance is determined by the external circuit configuration. To attain maximum power transfer, match the generator output impedance to the external circuit impedance. A table of the maximum short circuit currents and open circuit voltages available at each switch position will be found on the front panel adjacent to this switch.

Rotate the output POWER control fully clockwise.

If desired, this control may be rotated counterclockwise to reduce the output voltage.

Set the SELECTIVITY control to the SHARP position.

This position provides the maximum rejection of noise and harmonics. If a faster response time is desired, particularly when operating at lower frequencies, this control may be adjusted to either the broad or flat position. For typical frequency response characteristics in each of these positions, see Section 3.4.

Set the FINE TUNING control to the dot marking on the panel.

This control adjusts the detector to the exact generator frequency. Normally it may be left in its center position. However, to obtain the ultimate sensitivity for critical measurements, this control should be rotated to the position giving the maximum detector meter deflection at each operating frequency.

Turn the LOG-LINEAR SWITCH to the LOG position.

With the switch in this position the meter will read three decade ranges above the linear range without readjusting the sensitivity controls. Normally this will be the most convenient mode of

operation. However, to obtain the maximum detector sensitivity, or to use the detector for deflection type measurements, this switch should be in the linear position.

Turn the inner knob of the SENSITIVITY control fully clockwise. Turn the outer knob to 10^5. With these settings the meter deflection will be visible as a null is approached.

The inner control knob provides a continuous control of the detector sensitivity over a 20:1 range, and is most useful when making deflection type measurements. Normally it will be left at the extreme clockwise or maximum sensitivity position.

The outer control knob changes the sensitivity in approximate decade steps. With the continuous control at its maximum position and the LOG-LINEAR SWITCH in the linear position, the order of magnitude of the full scale sensitivity in microvolts is indicated by the panel engraving.

2.2 BRIDGE CONNECTIONS

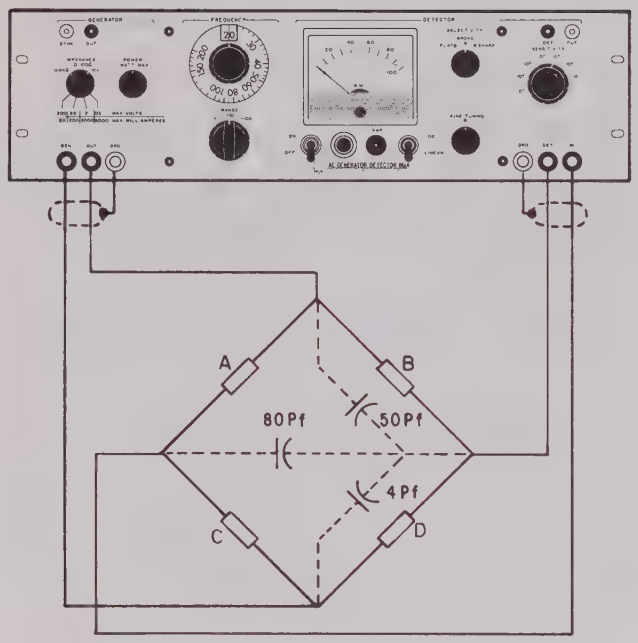


FIG. 2.2

Connect the generator output to the ungrounded corners of a bridge as shown in Fig. 2.2.

Terminal 1 is the guarded terminal with approximately 4 pf* shunt capacitance to ground. Terminal 2 has approximately 50 pf* to ground and should be placed across the bridge arm on which this capacitance will have the least effect.

Connect the detector input to the bridge as shown also in Fig. 2.2.

Terminal 1 is internally grounded. Terminal 2 has approximately 80 pf* shunt capacitance to ground.

For highest accuracy be sure that both the generator and the detector leads are shielded and that the bridge is grounded at one point only.

More detailed information regarding shielding and grounding will be found in Section 2.6.

* Plus lead capacitance

2.3 CONNECTIONS FOR VOLTAGE DIVIDER CALIBRATION

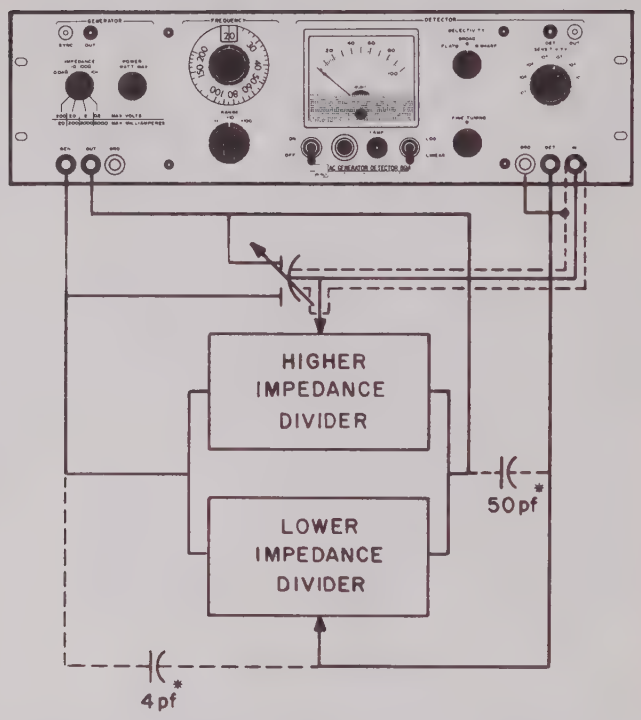


FIG. 2.3

Connect the dividers to the GEN OUT and DET IN terminals as shown in Fig. 2.3. (Note: DET 1 terminal is internally grounded.)

Normally it will be necessary to make a phase compensation between the two dividers. This is most easily accomplished by connecting a differential capacitor (50 pf approximate value) in the circuit as shown. This capacitor should be adjusted for a minimum reading on the null indicator.

Compare the calibrated divider settings to the readings on the divider being checked.

See Section 2.1 for null balance procedure.

For highest accuracy be sure that both the generator and the detector leads are shielded and that the circuit is grounded at one point only.

More detailed information regarding shielding and grounding will be found in Section 2.6.

* Plus lead capacitance

2.4 CONNECTIONS TO EXTERNAL INSTRUMENTS

2.4.1 OUTPUT JACKS

Two sets of special output jacks have been provided on the Model 861A to attain maximum utility of the instrument.

The SYNC OUT terminals provide a reference voltage at the generator frequency. This voltage has a constant amplitude of about 1.5 volts, and is unaffected by the setting of the generator output controls or the load connected to the generator. The output impedance is approximately 10 kilohms.

The DET OUT terminals provide an ac output signal with a voltage of about 8 volts RMS corresponding to a full scale linear meter deflection. The internal impedance of this voltage is less than 1 kilohm. A linear output up to at least 10 volts is available when the external loading is greater than 10 kilohms. This output is not affected by the position of the LOG-LINEAR switch.

Some suggested applications for these outputs are listed in the following instructions.

2.4.2 ELLIPTICAL (LISSAJOUS) CRO PATTERNS

To obtain an elliptical presentation on a cathode ray oscilloscope, connect the DET OUT terminals to the CRO vertical input, and the SYNC OUT terminals to the CRO horizontal input by means of shielded cable, as shown in Fig. 2.4.2.

The bridge may now be balanced in the normal manner. As a null is approached, the pattern should collapse to a horizontal, straight line, or a band if nonsynchronous noise components are present. A null adjustment should result in a minimum pattern width with no tilt from the horizontal axis.

The ellipse pattern is a desirable means of observing the output signal because it readily indicates the relative phase of the null, and also the separation of the fundamental null frequency from its harmonic components and noise frequencies. For this reason a greater selectivity can be achieved with a CRO than with the meter.

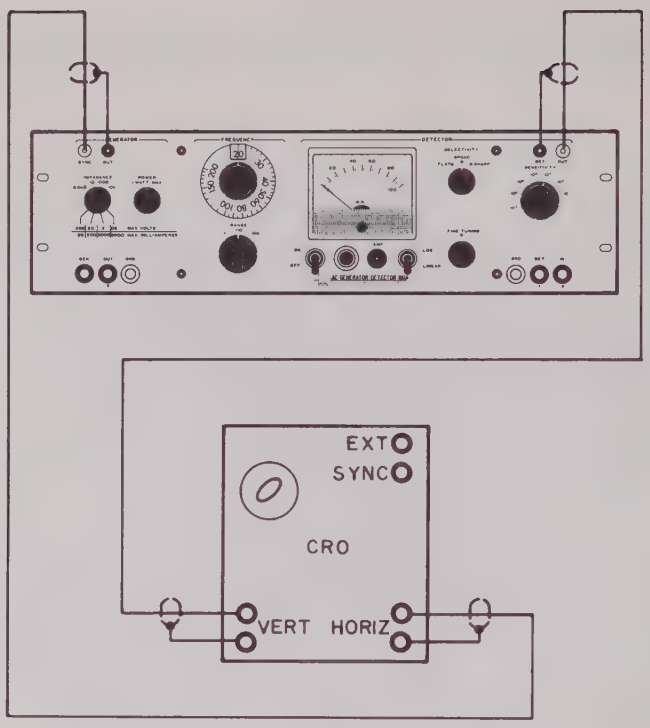


FIG. 2.4.2

2.4.3 SINUSOIDAL CRO PATTERNS

To obtain a sinusoidal presentation on an oscilloscope, connect the DET OUT terminals to the vertical input on the scope, and the SYNC OUT terminals to the CRO external sync terminals as shown in Fig. 2.4.3.

By using the external sync terminals on the CRO, the pattern will have horizontal stability even at null. The pattern will show phase reversal as a null is passed and the effects of individual bridge or divider controls can be easily separated.

2.4.4 REMOTE METER INDICATOR

A remote meter may be used by connecting it to the DET OUT terminals. A suitable instrument for this purpose would be a 10 to 30 volt AC voltmeter with an impedance of at least 1000 ohms per volt. The output will be linear to slightly over 10 volts, and will be limited to approximately 30 volts at which value the amplifier reaches saturation.

If a phase sensitive voltmeter is used, its reference voltage may be taken from the SYNC OUT terminals, as shown in Fig. 2.4.4. The detector FINE TUNING control can be used to produce a change in the phase angle of the signal as much as 150° or more at the DET OUT terminals. The change in phase angle results in some loss in gain.

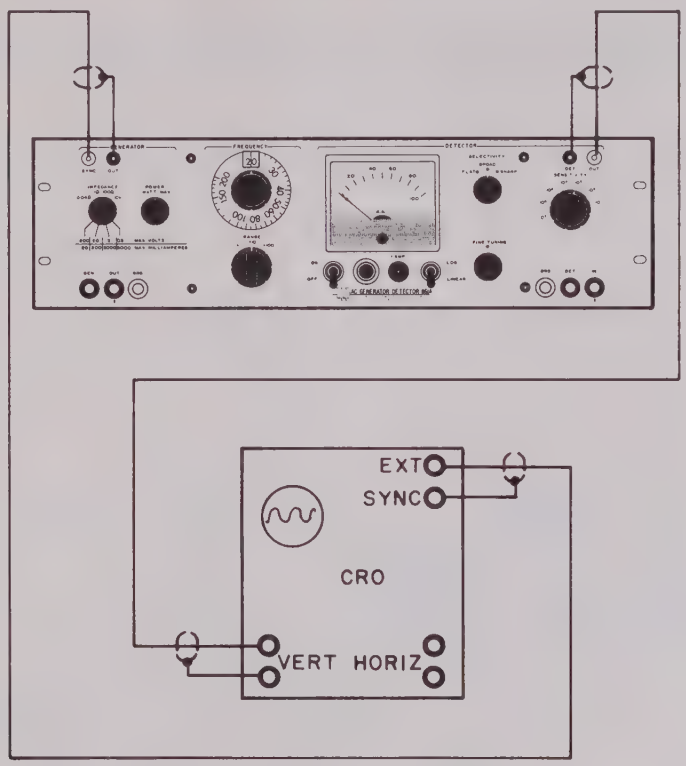


FIG. 2.4.3

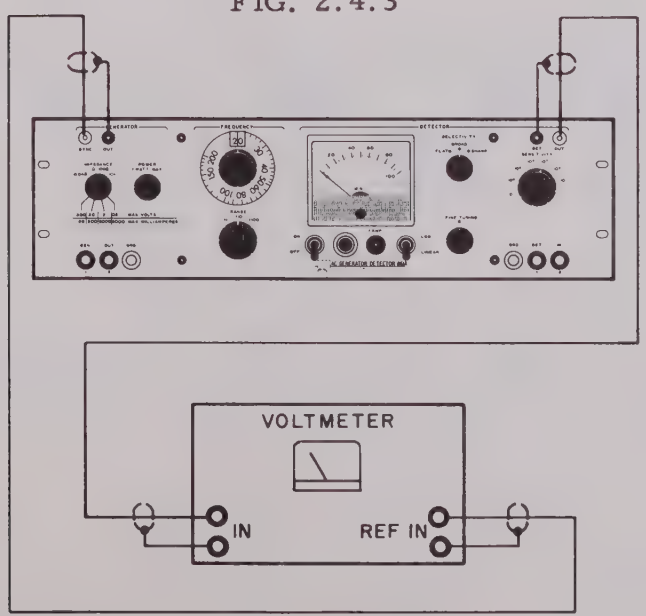


FIG. 2.4.4

2.4.5 HIGH ACCURACY FREQUENCY ADJUSTMENT

If it is desired to adjust the generator frequency more exactly than is possible with direct dial calibrations, the SYNC OUT terminals will provide a convenient source of voltage. This voltage may be used either with a direct reading frequency meter, or to provide a Lissajous pattern referred to a standard frequency source, as shown in Fig. 2.4.5.

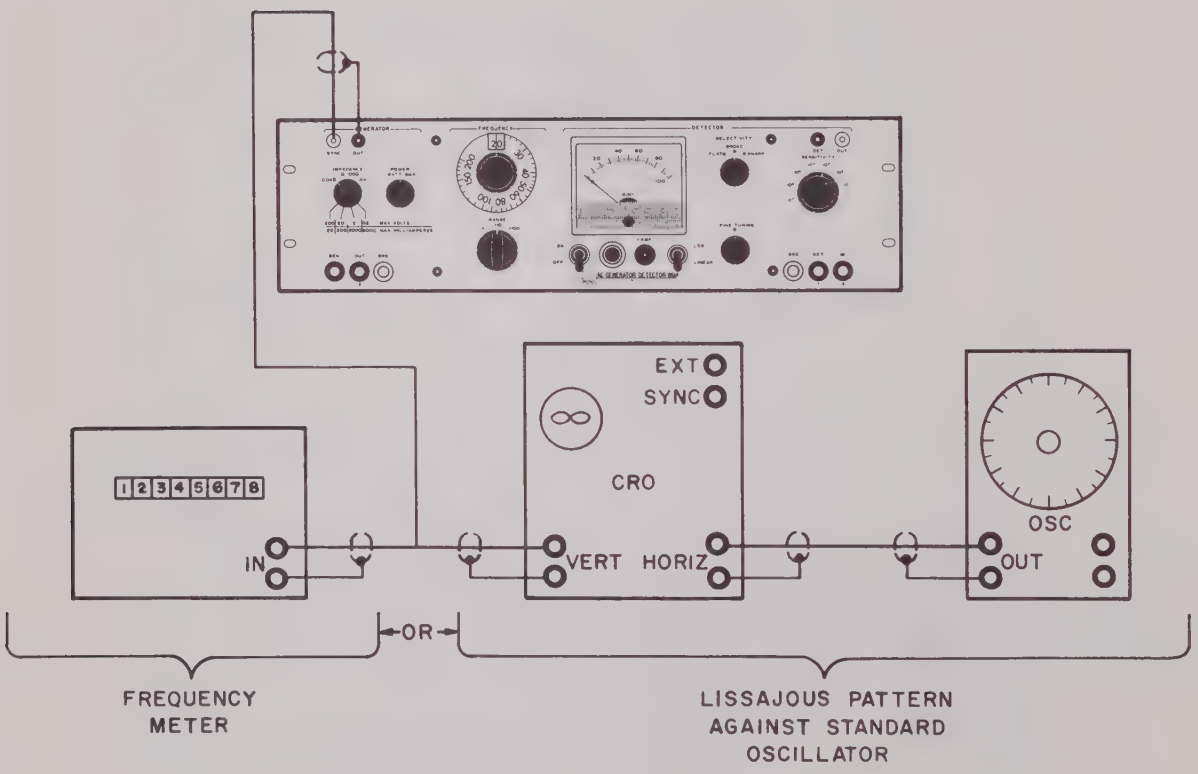


FIG. 2.4.5

2.5 MISCELLANEOUS APPLICATIONS

2.5.1 HIGH GAIN AMPLIFIER

The 861A detector may be used as a high gain, low noise amplifier. The amplifier may be operated in either the tuned or untuned mode.

The available linear output voltage at the DET OUT TERMINALS will be at least 10 volts into a 10 kilohm load, and will have a source impedance of approximately 200 ohms. The maximum available gain will be approximately 10^7.

When the detector is used as an amplifier the log-linear switch should be in the log position to keep the meter on scale with input overloads. This will not affect the amplifier output circuit.

2.5.2 WAVE ANALYZER

The 861A detector may also be used to determine the frequency spectrum of an audio signal. Typical variations in gain with frequency are shown in Section 3.4. For a more accurate measurement, the detector may be calibrated at each frequency. The following circuit is suggested when this calibaration is desired.

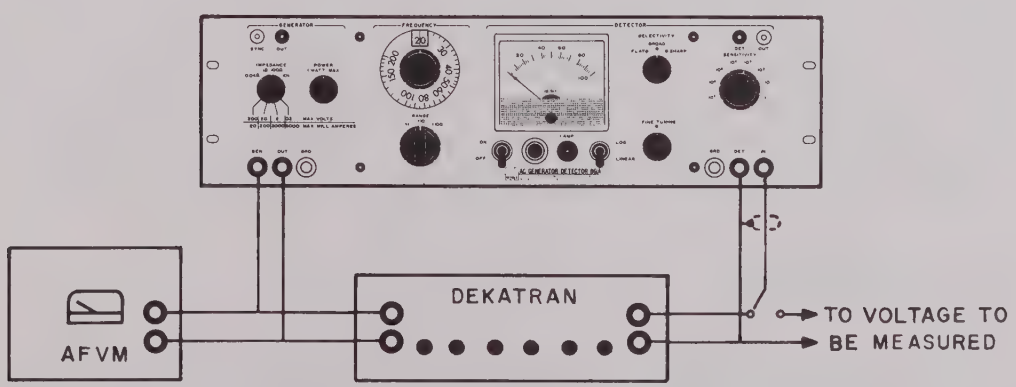


FIG. 2.5.2

The typical bandwidth at 3 db down is 7% of the center frequency, with a half and double frequency rejection of 40-45 db.

2.6 OPERATING PRECAUTIONS

2.6.1 GENERAL

Circuits which require the use of an 861A will normally demand special caution in shielding and grounding external equipment to assure reliable results. Stray capacitance and common impedance coupling of signals between the generator and detector circuits can produce an apparent null at a point considerably removed from the true null. In addition, any high level spurious signals - such as the line frequency and its harmonics - may produce undesirable amplifier overloading with consequent desensitization and modulation products, despite the highly selective amplifier characteristics.

2.6.2 SHIELDING

To prevent the introduction of electrostatically coupled stray signals, both the generator and detector connections must be completely shielded. A convenient and highly effective method of making these connections with a minimum stray capacitance to ground is by means of shorting links (ESI Part Number 3248) and shield covers (ESI Part Number 7307).

If circuit requirements dictate the use of longer connections, shielded cables with shield caps, extending completely over the terminals to the front panel, may be used. The cable should be of the type having low leakage through the shield braid. Double conductor shielded cable may be used for both the generator and detector connections. If, however, it is desired to retain the benefits of the guarded Generator output circuit, a concentric double shield or tri-axial cable should be employed with the inner conductor connected to terminal 1, the inner shield connected to terminal 2, and the outer shield connected to the ground terminal.

2.6.3 GROUNDING

To reduce the possibility of common impedance coupling the active measuring circuit should be grounded at one point only. Terminal 1 of the detector input is internally grounded to the chassis. It may be preferable to provide this ground lead independent of the shield, such as by the use of a two-conductor shielded, or tri-axial shielded cable.

When operating at power line frequency or its harmonics, special attention must be directed to the grounding. To provide greater flexibility, the 861A chassis is isolated from the power line ground. If external line operated equipment is connected to the SYNC OUT or DET OUT terminals, a ground connection will most likely be established by this path. If no external equipment is used, it may be found helpful to connect an external ground to the 861A chassis. As with the measurement circuit, multipath grounding should be avoided.

3.1 DETECTOR CIRCUIT DESCRIPTION

The detector is a high gain audio amplifier, continuously tunable from 20 cycles to 20 kilocycles in three bands. It employs four amplifier stages with shunt limiting between each stage to insure fast recovery from large overloads. Two tuned stages are used for very high rejection of any signals with other than the desired frequency. The detector block diagram is shown in Fig. 3.1.

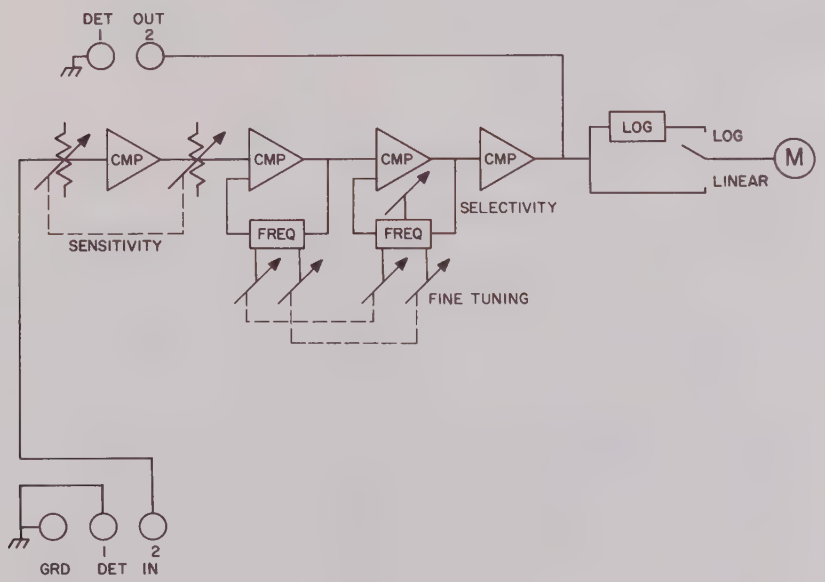


FIG. 3.1

The input signal, after passing through the input attenuator, is amplified by a low noise, cascode amplifier stage. Next it passes through the interstage attenuator to the first tuned amplifier stage. This consists of a pentode amplifier direct-coupled to a cathode follower output. The negative feedback loop for this stage consists of a tunable frequency rejection network (described in Section 3.3). The signal is further amplified by an identical tuned stage and by the output amplifier, after which it is applied to the detector output terminals and to the meter rectifier. A network in the DC meter circuit provides selection of either compressed or linear presentation of the reading.

3.2 GENERATOR CIRCUIT DESCRIPTION

The generator is composed of a variable frequency oscillator, a power amplifier, and an impedance matching output network. The block diagram is shown in Fig. 3.2

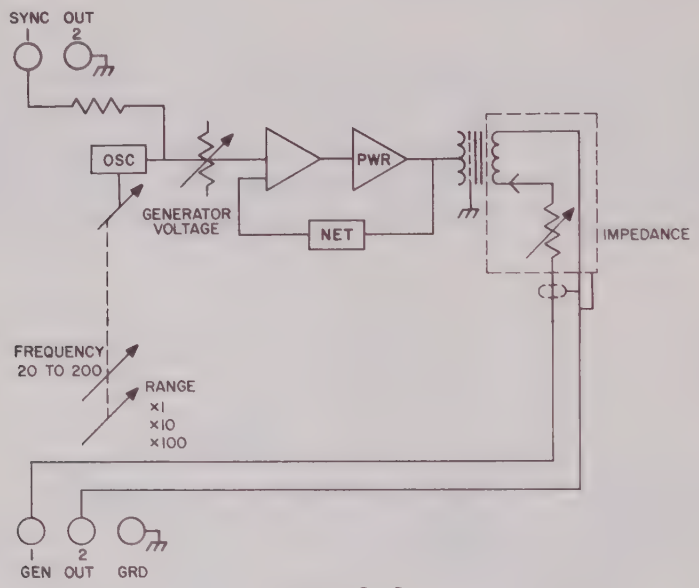


FIG. 3.2

The oscillator is a pentode-cathode follower pair, similar to that used in the detector. Positive cathode-to-cathode feedback is used to cause the circuit to oscillate. The frequency of this oscillation is determined by a tunable rejection network in a negative feedback loop from the output cathode to the pentode grid. A parallel negative feedback loop contains a temperature compensated thermistor network to stabilize the oscillator amplitude.

The power amplifier consists of a triode amplifier, direct-coupled to a split load phase inverter, followed by a push-pull pentode output stage. Overall negative feedback from a tertiary winding of the output transformer to the cathode of the input triode is utilized to reduce distortion.

The output transformer is of a special double shielded design. It minimizes the stray coupling between the amplifier and external circuit elements. A tapped secondary winding permits the selection of an optimum output impedance level for the particular measurement being performed. Associated with each tap is a shielded power limiting impedance to protect the external load elements.

3.3 TUNING NETWORK

The variable frequency tuning network employed in both the detector and generator portions of the 861A is of a unique design which makes it possible to cover a 10 to 1 frequency range by means of a single resistive divider. A simplified diagram of this network is shown in Fig. 3.3A.

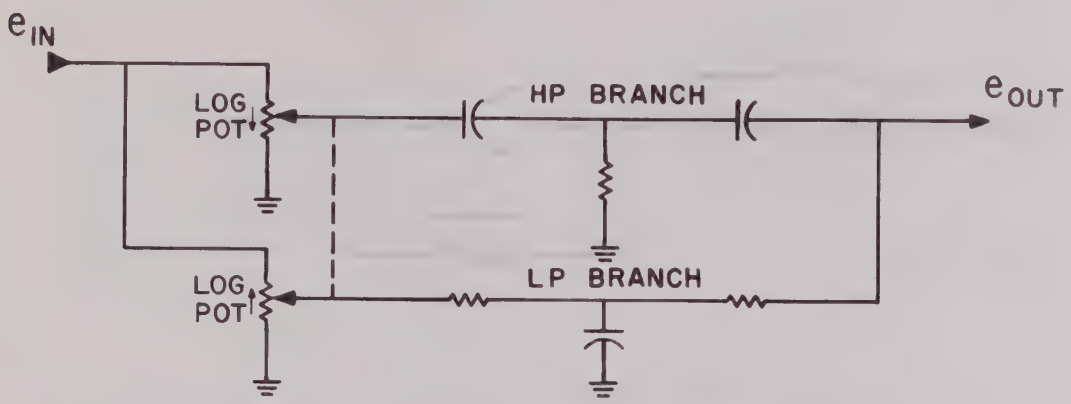


FIG. 3.3A

For clarity, the tuning attenuators have been shown as a pair of ganged, logarithmic resistive dividers. In the actual circuit, a center tapped, linear potentiometer is resistance loaded to produce a very close approximation to this configuration.

An analysis of this circuit will show that if the product of the ratios of the high pass and low pass branch attenuators is made constant over the tuning range - as would be achieved with the logarithmic attenuators - a perfect null will be obtainable over the entire tuning range. For example, the ratios at the top, geometric mean, and bottom frequencies of any range are as follows:

FREQUENCY	HIGH PASS RATIO	LOW PASS RATIO	RATIO PRODUCT
TOP	0.1	1	0.1
MEAN	0.31	0.31	0.1
BOTTOM	1	0.1	0.1

To obtain the changes in tuning range, the three capacitors in the high pass and low pass branches are switched in decade increments.

Since this network produces a null at the tuned frequency, it must be employed in a negative feedback circuit to achieve the desired peaked response. A simplified diagram of the operational amplifier type circuit is shown in Fig. 3.3B.

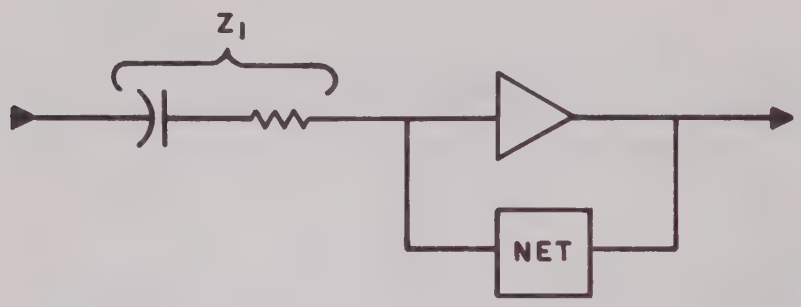


FIG. 3.3B

One unique feature of this circuit is that if the input impedance Z_1 is properly proportioned with respect to the network parameters, the response curve will be symmetrical about the center frequency. It will continue to fall indefinitely at both the high and low frequencies with a 6 db per octave rate. This is illustrated in the typical frequency response curves shown in Section 3.4.

3.4 TYPICAL OPERATING PERFORMANCE CURVES

The following curves describe graphically some of the more important operating characteristics of the 861A Generator-Detector.

3.4.1 FREQUENCY RESPONSE

Frequency response plots with the detector tuned to 100 cps, 1 kc, and 10 kc are shown in Fig. 3.4.1. It will be noted that there is only one curve for the FLAT position of the selectivity control. The reason for this is that the detector is untuned when the selectivity control is in the FLAT position, therefore, the same curve applies for all frequencies. The peak response for each range is given by the set of gain variation curves at the top of the graph.

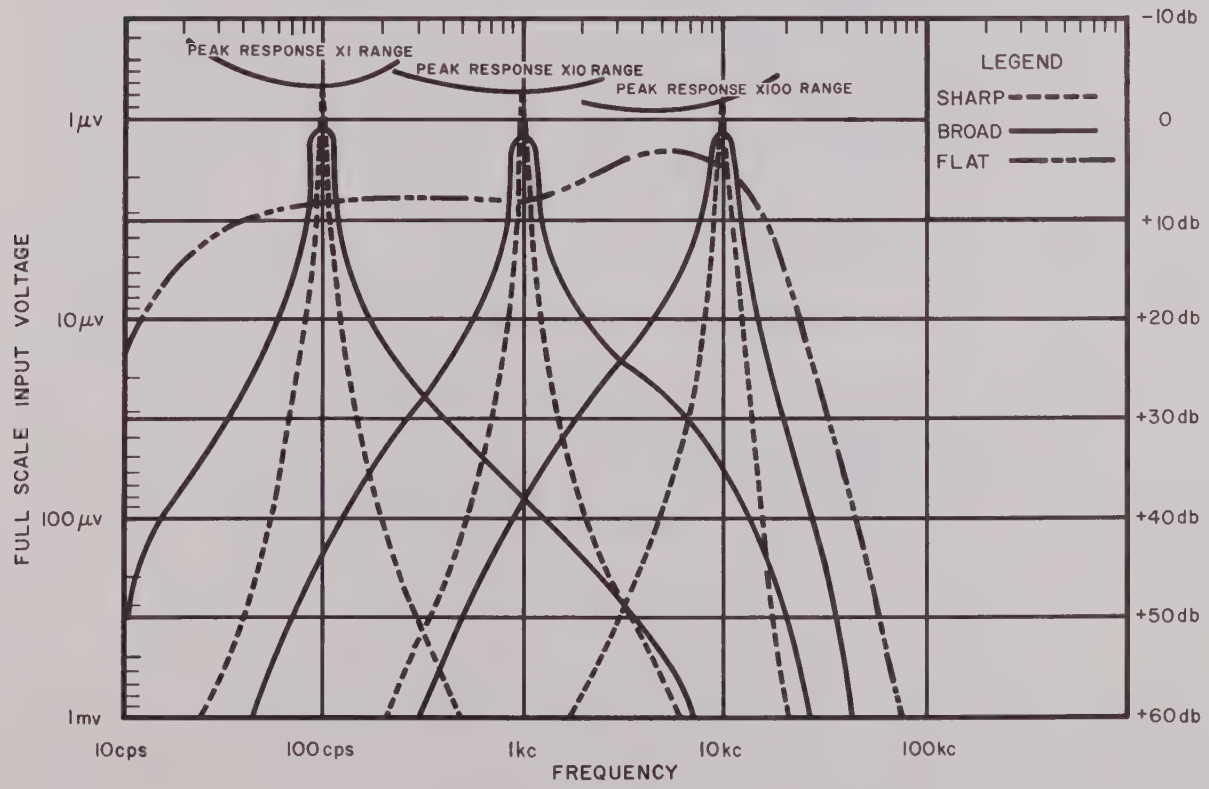


FIG. 3.4.1

3.4.2 NOISE VOLTAGE AND CURRENT

Equivalent input noise voltage and noise current variations over the tuning range are shown for the detector in Fig. 3.4.2. The increase in noise at the higher frequencies is caused principally by the increased bandwidth since the bandwidth is essentially a constant percentage of the frequency to which the detector is tuned.

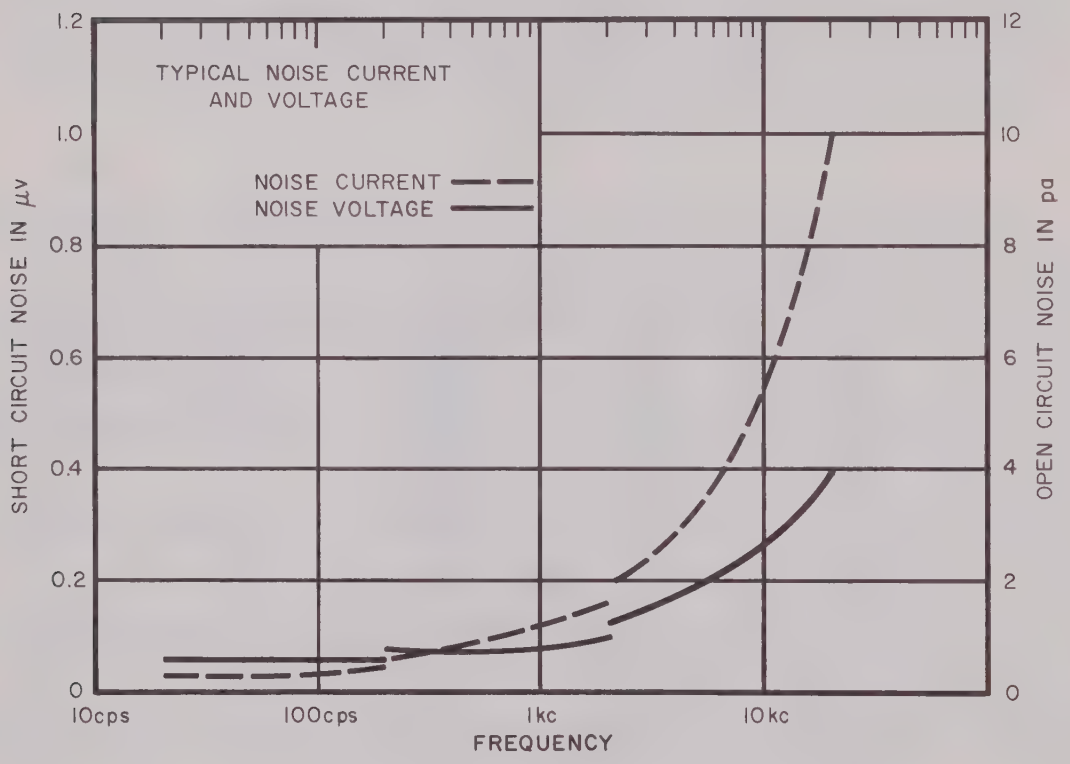


FIG. 3.4.2

3.4.3 NOISE POWER

Typical variations in the 1 kc detector equivalent input noise power over a wide range of source impedances is shown in Fig. 3.4.3. It may be noted from this curve that the noise power essentially reaches the theoretical limit for a 100 cycle equivalent noise bandwidth over several decades of source impedances.

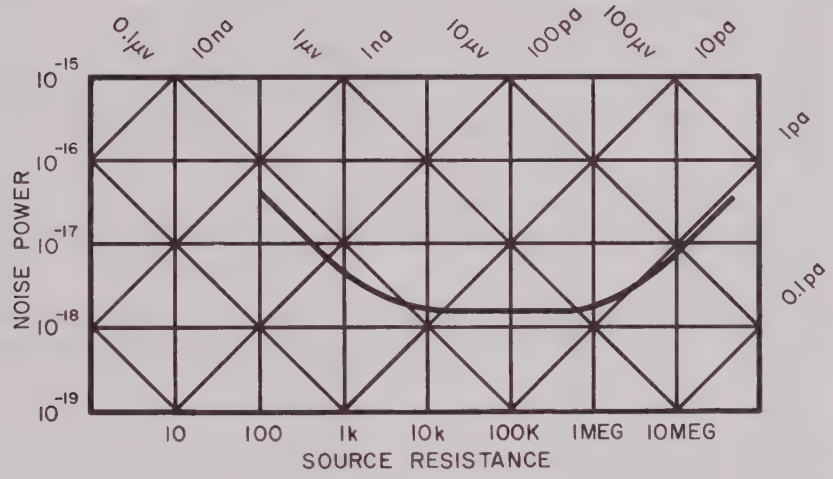


FIG. 3.4.3

3.4.4 AMPLITUDE RESPONSE

Characteristic amplitude response of the detector meter is shown in Fig. 3.4.4 for both the linear and the logarithmic modes of operation. As this curve illustrates, a detectable change in the deflection of the meter occurs for input signals of over a thousand times the normal linear full scale reading when used in the log position.

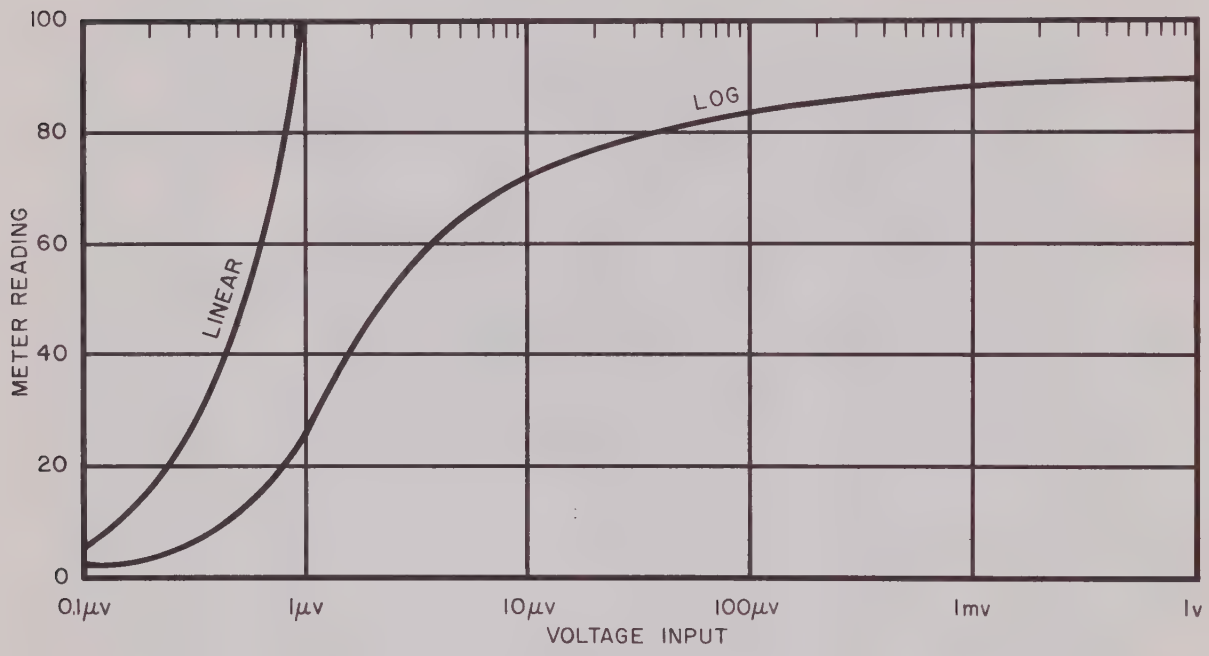


FIG. 3.4.4

3.4.5 GENERATOR OUTPUT

Typical variations in the generator output voltage and current over the tuning range are shown in Fig. 3.4.5.

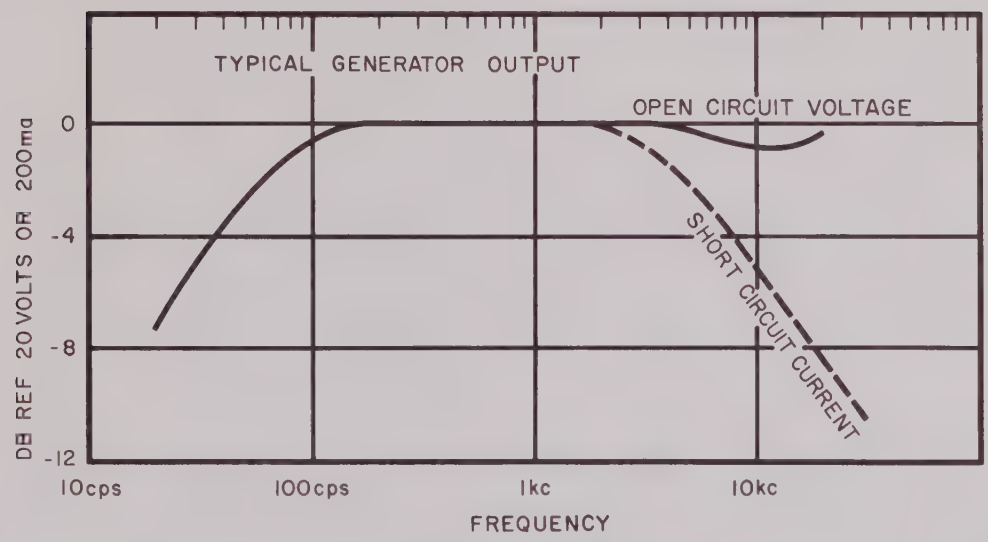


FIG. 3.4.5

4.1 TROUBLE SHOOTING

4.1.1 GENERAL

This instrument has been designed to give trouble free service with a minimum of maintenance required. If, however, it should be necessary to correct any difficulties which might arise, the following section should provide maintenance personnel with sufficient information to effect the required corrective action. It will be assumed that maintenance personnel are familiar with the operating instructions and theory of operation as contained in Sections II and III.

In the event of unusual difficulties which cannot be defined by service personnel, please write or phone the factory or nearest field representative, giving the model and serial number of the instrument, the nature of the trouble, and any test procedures used to isolate the probable cause.

4.1.2 REMOVAL OF THE COVER

The instrument cover may be removed by taking out the two screws located on the rear portion and pulling the cover straight back. Caution must be exercised not to strike any of the tubes or other components during the removal or replacement of the cover.

4.1.3 TUBE REPLACEMENT

It is probable that the majority of service required will be replacement of the vacuum tubes. Only three tube types are used in this instrument, 4 - 6BM8/ECL82, 4 - 6BL8/ECF80, and 1 - 7308. Normally any standard commercial vacuum tube may be used without special matching or testing required. It may be found, however, that there is some variation in the noise level with different tubes, and for the most critical applications it may be desired to select a tube for the lowest possible

short circuit noise level. The tube contributing principally to the noise level is the type 7308, V_1. In the event that this tube type is not immediately available, it may be replaced directly by either a type 6922 or 6DJ8. Although these latter tubes are electrically identical, they are somewhat more susceptable to mechanical vibrations.

The type 6BL8, V2, may, on rare occasions, contribute some excess noise. This may be determined by observing the noise level with the sensitivity range and vernier controls both in their counterclockwise position. This tube may then be interchanged with the similar types found in V3, V4, and V6 to yield the minimum noise level.

4.1.4 VOLTAGE MEASUREMENTS

Typical voltage measurements are indicated on the circuit diagrams for the generator and detector.

The DC voltages are all referenced to the chassis potential and are measured with a standard 11 megohm input impedance vacuum tube voltmeter. The measured readings should agree with those shown on the diagram within ±10%. All DC voltages are measured with the detector sensitivity and generator power controls in their minimum positions.

The AC voltages are measured with a sensitive 10 megohm input impedance AC vacuum tube voltmeter, and are all referenced to chassis potential. Because of the difficulty of thoroughly shielding the test probe when making these measurements, it is desirable to monitor the detector output with an oscilloscope to insure that the stray coupling thus introduced is not causing spurious oscillations, or that the added capacitance of the test lead is not appreciably loading any high impedance circuits.

An alternative and generally preferable method of avoiding spurious oscillations in AC signal tracing is to insert a voltage of the appropriate value at the particular test point, and observe the output voltage with a meter connected to the DET OUT terminals. To prevent undue loading of this test signal, it must be derived from a low impedance source. A convenient method for obtaining this voltage is to use a Dekatran ® Decade Voltage Divider driven from a low impedance oscillator. The measured AC voltage reading should be within ±25% of those indicated on the circuit diagram.

4.1.5 REPAIR OF PRINTED CIRCUIT ASSEMBLIES

The printed circuit boards employed in this instrument have been carefully designed and manufactured to give long, reliable performance. If it should become necessary to replace any components, the following procedure is suggested.

It is recommended that a soldering iron of approximately 50 watts, with a small, well tinned tip be used. To avoid delaminating the copper conductor from the board, apply the iron for the shortest possible length of time.

To remove components with wire leads, such as resistors or capacitors, heat the component leads on the copper conductor side of the circuit board. Always apply the tip of the iron to the component lead rather than directly to the copper conductor. See Fig. 4.1.5. Pull gently on the lead from the component side with a pair of pliers or other small instrument hooked under the bent lead.

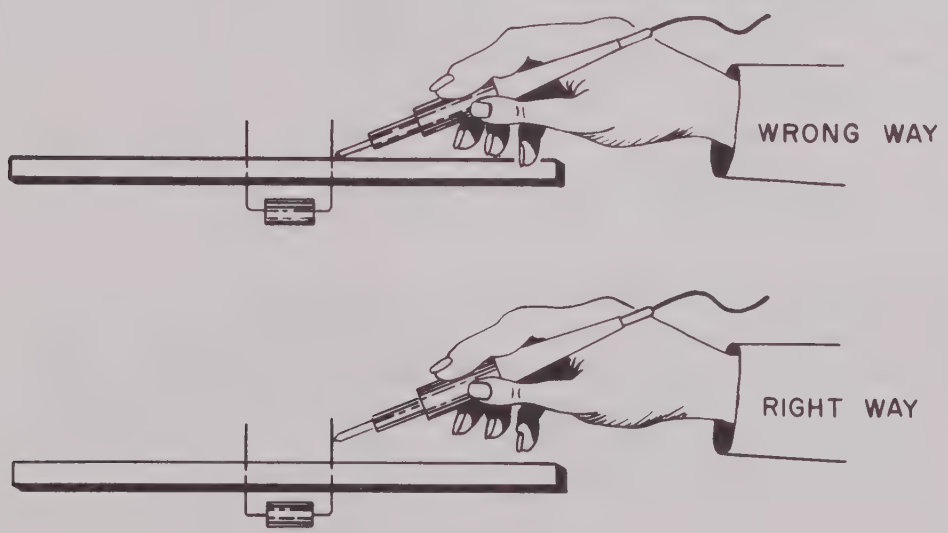


FIG. 4.1.5

To remove multiterminal devices such as tube sockets, heat each terminal in succession and lift only slightly. It will be necessary to repeat this procedure several times before the component can be removed. NOTE: Special attachments are made for soldering irons for removing multiterminal devices.

After the component has been removed, quickly reheat the solder and insert the point of an awl into the hole from the conductor side. If it is necessary to clean the copper conductor before resoldering, use some fine sandpaper or gently scrape with a knife.

To repair a break in the copper conductor, place a short piece of tinned copper wire across the break, and solder on each side. The wire should overlap the break by at least 1/4 inch on each side.

When replacing components, use only the best quality rosin core solder with no other fluxes. Bend the component leads to fit the hole spacing, and insert them in the board. (All hole centers are 3/4" for 1/2 and 1 watt resistors.) Do not force the component leads into the holes. Redrill the holes with an appropriately sized drill if the leads cannot be inserted easily. Holding the component tight against the assembly board, apply the soldering iron to the component lead on the copper side of the board and resolder. If the component is a semiconductor device, it is recommended that the lead be held on the component side with a pair of long nose pliers to act as a heat sink.

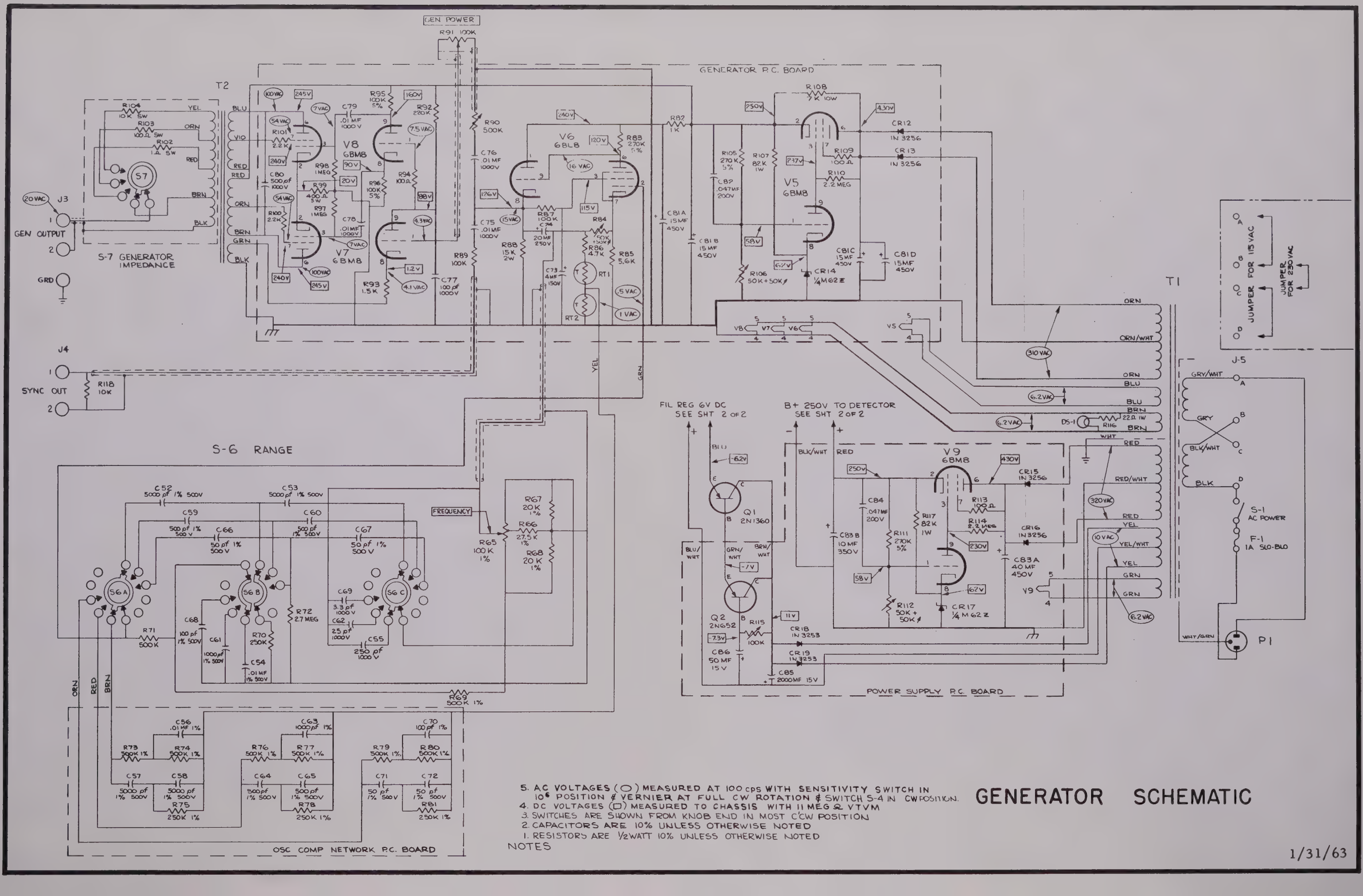
After finishing the soldering operation, clean off the excess flux with some noncorrosive solvent such as alcohol or Freon. If desired the repaired area may be protected by applying a small quantity of an insulating varnish.

4.1.6 TRIMMER RESISTOR ADJUSTMENTS

It may be noted from the circuit diagrams that there are several trimmer resistors in the circuit. These trimmers are for initial factory adjustment, and should not be touched during normal maintenance. If, however, any parts associated with these trimmers require replacement, one of the following adjustments may be necessary to restore proper performance.

CIRCUIT	FUNCTION	ADJUST FOR
R_{33}	Detector gain	Full scale meter deflection at 5 kc with 1 microvolt input signal.

CIRCUIT	FUNCTION	ADJUST FOR
R_{84}	Oscillator amplitude	1.2-1.5 volts output at SYNC OUT terminals. For minimum distortion, use setting providing amplitude slightly in excess of that required for reliable oscillation over entire frequency range.
R_{90}	Generator output	Open circuit generator output of 20 volts at 1 kc with 100 ohms output impedance.
R_{106}	Generator high voltage regulator	250 volts DC at regulator output.
R_{112}	Detector high voltage regulator	250 volts DC at regulator output.
R_{115}	Detector filament filter	6.2 volts DC at filter output.

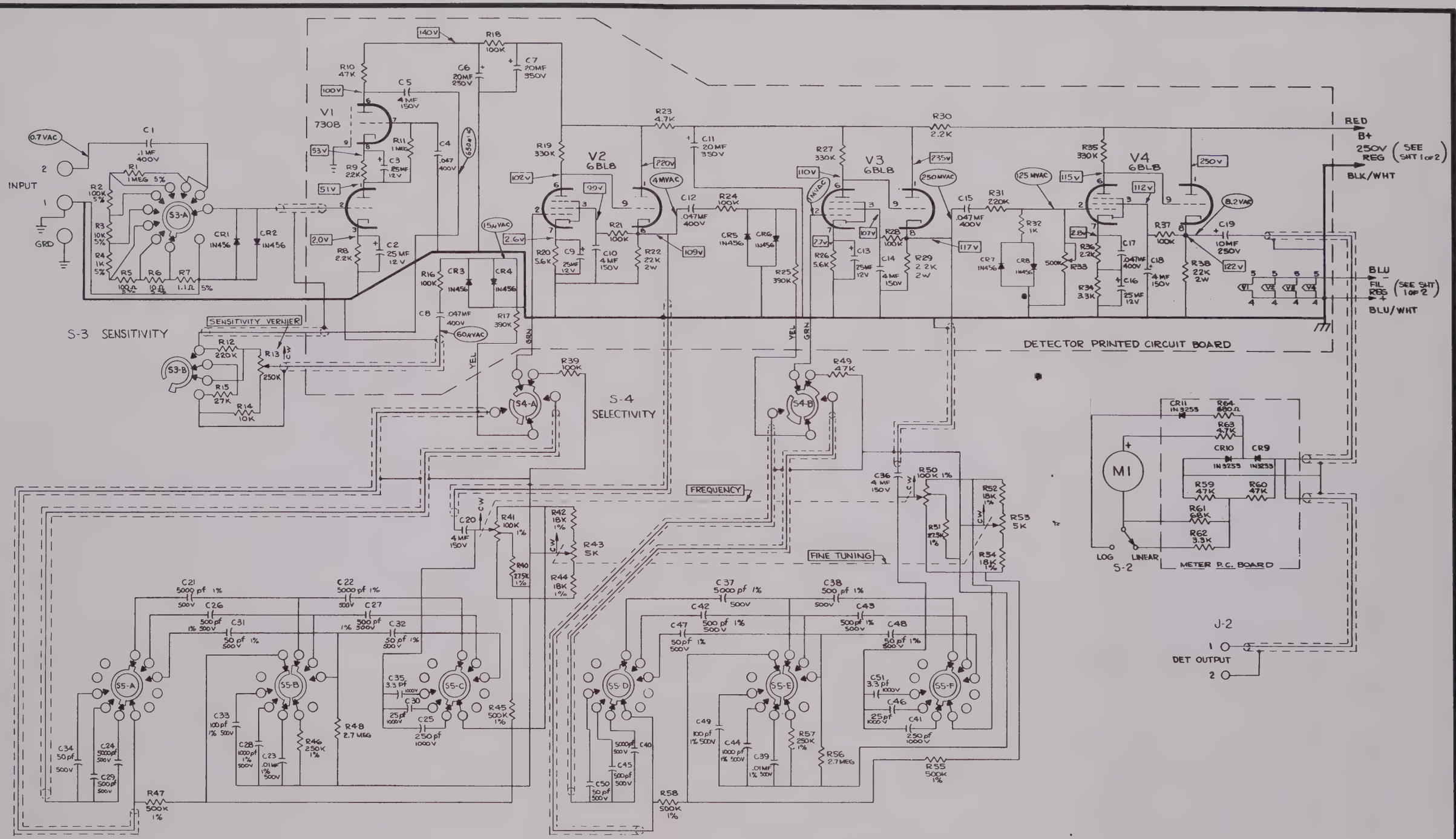


NOTES

1. RESISTORS ARE ½WATT 10% UNLESS OTHERWISE NOTED
2. CAPACITORS ARE 10% UNLESS OTHERWISE NOTED
3. SWITCHES ARE SHOWN FROM KNOB END IN MOST C'CW POSITION
4. DC VOLTAGES (□) MEASURED TO CHASSIS WITH 11 MEG Ω VTVM
5. AC VOLTAGES (○) MEASURED AT 100 cps WITH SENSITIVITY SWITCH IN 10^6 POSITION & VERNIER AT FULL CW ROTATION & SWITCH S-4 IN CW POSITION.

GENERATOR SCHEMATIC

1/31/63



5. AC VOLTAGES (○) MEASURED AT 100 cps WITH SENSITIVITY SWITCH IN 10^6 POSITION & VERNIER AT FULL CW ROTATION & SWITCH S-4 IN CW POSITION.
4. DC VOLTAGES (□) MEASURED TO CHASSIS WITH 11 MEG Ω VTVM
3. SWITCHES ARE SHOWN FROM KNOB END IN MOST C'CW POSITION
2. CAPACITORS ARE 10% UNLESS OTHERWISE NOTED
1. RESISTORS ARE ½WATT 10% UNLESS OTHERWISE NOTED

NOTES

DETECTOR SCHEMATIC

1/31/63

4.3 PARTS LIST

The following parts list is in alpha numerical order of the circuit reference designator. Miscellaneous parts are included at the end of the list. Manufacturer of the part is given in a code number according to the Federal Supply Code for Manufacturers; see list of manufacturers below. Parts recommended as spare parts to sustain operation in isolated locations are indicated in the recommended spare parts column.

Parts manufactured by Electro Scientific Industries must be ordered from the factory. When ordering parts from the factory, include the following information.

Model and serial number of the instrument
Electro Scientific Industries part number
Circuit reference designator
Description of part

CODE LIST OF MANUFACTURERS

01121	ALLEN-BRADLEY CO. Milwaukiee, Wis.
02114	FERROXCUBE CORP. OF AMERICA, Saugerties, N.Y.
02735	RCA SEMICONDUCTOR AND MATERIALS DIVISION OF RADIO CORP. OF AMERICA Somerville, N.J.
04713	MOTOROLA, INC., SEMICONDUCTOR PRODUCTS DIVISION Phoenix, Ariz.
11837	ELECTRO SCIENTIFIC INDUSTRIES, INC. Portland, Oreg.
12697	CLAROSTAT MFG. CO., INC. Dover, N. H.
19701	ELECTRA MFG. CO. Kansas City, Mo.
56289	SPRAGUE ELECTRIC CO. North Adams, Mass.

CODE LIST OF MANUFACTURERS (Continued)

63743	WARD, LEONARD, ELECTRIC CO. Mount Vernon, N, Y.
65092	WESTERN WIRE PRODUCTS CO. St. Louis, Mo.
71590	CENTRALAB DIVISION OF GLOBE-UNION INC. Milwaukee, Wis.
71785	CINCH MFG. CO., DIVISION OF UNITED CARR FASTENER CORP. Chicago, Ill.
72619	DIALIGHT CORP. Brooklyn, N.Y.
72653	GENERAL CEMENT DIVISION OF TEXTRON INC. Rockford, Ill.
73445	AMPEREX ELECTRONIC CORP., Hicksville, N.Y.
73586	CIRCLE F MFG. CO. Trenton, N. J.
75042	CONNECTOR DIVISION OF INTERNATIONAL RESISTANCE CO. Philadelphia, Pa.
75915	LITTELFUSE, INC. Des Plaines, Ill.
76854	OAK MFG. CO. Chicago, Ill.
83740	EVEREADY DIVISION OF NATIONAL CARBON DIVISION OF UNION CARBIDE CORP. New York, N.Y.
84171	ARCO ELECTRONICS, INC. Great Neck, N.Y.
93332	SYLVANIA ELECTRIC PRODUCTS INC., SEMICONDUCTOR PRODUCTS DIVISION Woburn, Mass.

Ckt Ref	Description	Mfr	ESI Part No.	Qty Used	Recm SP
C_1	Cap., Fxd, Paper, 0.1μf ±10%, 400 wvdc, Mfr PN 4TM-P10	56289		1	
C_2	Cap., Fxd, Elect., 25μf -10% +100%, 12 wvdc, Mfr PN TE 1131	56289		5	
C_3	Same as C_2				
C_4	Cap., Fxd, Paper, 0.047μf ±10%, 400 wvdc, Mfr PN 4SE-S47	56289		5	
C_5	Cap., Fxd, Elect., 4μf -10% +100%, 150 wvdc, Mfr PN TE 1503	56289		7	
C_6	Cap., Fxd, Elect., 20μf -10% +100%, 250 wvdc, Mfr PN TVA 1508	56289		2	
C_7	Cap., Fxd, Elect., 20μf -10% +100%, 350 wvdc, Mfr PN TVA 1608	56289		2	
C_8	Same as C_4				
C_9	Same as C_2				
C_{10}	Same as C_5				
C_{11}	Same as C_7				
C_{12}	Same as C_4				
C_{13}	Same as C_2				

Ckt Ref	Description	Mfr	ESI Part No.	Qty Used	Recm SP
C_{14}	Same as C_5				
C_{15}	Same as C_4				
C_{16}	Same as C_2				
C_{17}	Same as C_4				
C_{18}	Same as C_5				
C_{19}	Cap., Fxd, Elect., 10µf -10% +100%, 250 wvdc, Mfr PN TVA1504	56289		1	
C_{20}	Same as C_5				
C_{21}	Cap., Fxd, Mica, 5000 pf 1%, 500 wvdc, Mfr PN CM-30-D-502F	84171		8	
C_{22}	Same as C_{21}				
C_{23}	Cap., Fxd, Mica, 10000 pf 1%, 500 wvdc, Mfr PN CM-35-D-103F	84171		4	
C_{24}	Cap., Fxd, Ceramic, 5000 pf ±10%, 1000 wvdc, Mfr PN 10TS-D50	56289		2	
C_{25}	Cap., Fxd, Ceramic, 250 pf ±10%, 1000 wvdc, Mfr PN 10TS-T25	56289		3	
C_{26}	Cap., Fxd, Mica, 500 pf ±1%, 500 wvdc, Mfr PN CM19D501F	84171		8	
C_{27}	Same as C_{26}				
C_{28}	Cap., Fxd, Mica, 1000 pf 1%, 500 wvdc, Mfr PN CM19D102F	84171		4	

Ckt Ref	Description	Mfr	ESI Part No.	Qty Used	Recm SP
C_{29}	Cap., Fxd, Ceramic, 500 pf ±10%, 1000 wvdc, Mfr PN 10TS-T50	56289		3	
C_{30}	Cap., Fxd, Ceramic, 25 pf ±10%, 1000 wvdc, Mfr PN 10TS-Q25	56289		2	
C_{31}	Cap., Fxd, Mica, 50 pf 1%, 500 wvdc, Mfr PN CM15D50F	84171		8	
C_{32}	Same as C_{31}				
C_{33}	Cap., Fxd, Mica, 100 pf 1%, 500 wvdc, Mfr PN CM15D101F	84171		4	
C_{34}	Cap., Fxd, Ceramic, 50 pf ±10%, 1000 wvdc, Mfr PN 10TS-Q50	56289		2	
C_{35}	Cap., Fxd, Ceramic, 3.3 pf ±10%, 1000 wvdc, Mfr PN 10TS-V33	56289		2	
C_{36}	Same as C_5				
C_{37}	Same as C_{21}				
C_{38}	Same as C_{21}				
C_{39}	Same as C_{23}				
C_{40}	Same as C_{24}				
C_{41}	Same as C_{25}				
C_{42}	Same as C_{26}				
C_{43}	Same as C_{26}				
C_{44}	Same as C_{28}				
C_{45}	Same as C_{29}				

Ckt Ref	Description	Mfr	ESI Part No.	Qty Used	Recm SP
C_{46}	Same as C_{30}				
C_{47}	Same as C_{31}				
C_{48}	Same as C_{31}				
C_{49}	Same as C_{33}				
C_{50}	Same as C_{34}				
C_{51}	Same as C_{35}				
C_{52}	Same as C_{21}				
C_{53}	Same as C_{21}				
C_{54}	Same as C_{23}				
C_{55}	Same as C_{25}				
C_{56}	Same as C_{23}				
C_{57}	Same as C_{21}				
C_{58}	Same as C_{21}				
C_{59}	Same as C_{26}				
C_{60}	Same as C_{26}				
C_{61}	Same as C_{28}				
C_{62}	Same as C_{30}				
C_{63}	Same as C_{28}				
C_{64}	Same as C_{26}				
C_{65}	Same as C_{26}				
C_{66}	Same as C_{31}				
C_{67}	Same as C_{31}				

Ckt Ref	Description	Mfr	ESI Part No.	Qty Used	Recm SP
C_{68}	Same as C_{33}				
C_{69}	Same as C_{35}				
C_{70}	Same as C_{33}				
C_{71}	Same as C_{31}				
C_{72}	Same as C_{31}				
C_{73}	Same as C_{5}				
C_{74}	Same as C_{6}				
C_{75}	Cap., Fxd, Ceramic, 0.01µf ±10%, 1000 wvdc, Mfr PN 10TS-S10	56289		4	
C_{76}	Same as C_{75}				
C_{77}	Cap., Fxd, Ceramic, 100 pf ±10%, 1000 wvdc, Mfr PN 10TS-T10	56289		1	
C_{78}	Same as C_{75}				
C_{79}	Same as C_{75}				
C_{80}	Same as C_{29}				
$C_{81A - D}$	Cap., Fxd, Elect., 15, 15, 15, 15µf -10% +100%, 450 wvdc, Mfr PN 48778	56289		1	
C_{82}	Cap., Fxd, Paper, 0.047µf ±10%, 200 wvdc, Mfr PN 2TM-S47	56289		2	
$C_{83A, B}$	Cap., Fxd, Elect., 40µf and 10µf, -10% +100%, 450 wvdc and 300 wvdc	56289	1910	1	

Ckt Ref	Description	Mfr	ESI Part No.	Qty Used	Recm SP
C_{84}	Same as C_{82}				
C_{85}	Cap., Fxd, Elect., 2000μf -10% +100%, 15 wvdc	56289	1911	1	
C_{86}	Cap., Fxd, Elect., 50μf -10% +100%, 15 wvdc	56289	15836	1	
CR_{1-8}	Diode, Silicon, Mfr PN 1N456A	93332		8	
CR_{9-11}	Diode, Silicon, Mfr PN 1N3253	02735		5	
$CR_{12,13,15,16}$	Diode, Silicon, Mfr PN 1N3256	02735		4	
$CR_{14,17}$	Diode, Silicon, Mfr PN 1/4M62Z	04713		2	
$CR_{18,19}$	Same as CR_9				
DS_1	Lamp, #47	83740		1	1
F_1	Fuse cartridge, 1 amp SB, 250v	75915		1	2
J_1	Binding Post Cap, Black	11837	1170	4	
J_1	Binding Post Cap, Gold	11837	1172	2	
J_2	Banana Jack, Black, Mfr PN GC7742	72653		2	
J_2	Banana Jack, Red, Mfr PN GC7741	72653		2	
J_3	Same as J_1				
J_4	Same as J_2				

Ckt Ref	Description	Mfr	ESI Part No.	Qty Used	Recm SP
J_5	Terminal Strip	71785		1	
M_1	Meter	65092	9167	1	
P_1	Line Cord	11837	2520	1	
Q_1	Transistor 2N1360	04713		1	
Q_2	Transistor 2N652	04713		1	
R_1	Res., Fxd, Comp, 1 meg ±5%, 1/2 w, Mfr PN EB-1055	01121		1	
R_2	Res., Fxd, Comp, 100K ±5%, 1/2 w, Mfr PN EB-1045	01121		1	
R_3	Res., Fxd, Comp, 10K ±5%, 1/2 w, Mfr PN EB-1035	01121		1	
R_4	Res., Fxd, Comp, 1K ±5%, 1/2 w, Mfr PN EB-1025	01121		1	
R_5	Res., Fxd, Comp, 100Ω ±5%, 1/2 w, Mfr PN EB-1015	01121		1	
R_6	Res., Fxd, Comp, 10Ω ±5%, 1/2 w, Mfr PN EB-1005	01121		1	
R_7	Res., Fxd, WW, 1.1Ω BWH5%, 1/2 w, Mfr PN BW-1/2	75042		1	
$R_{8, 9}$	Res., Fxd, Comp, 2.2K ±10%, 1/2 w, Mfr PN EB-2221	01121		6	
R_{10}	Res., Fxd, Comp, 47K ±10%, 1/2 w, Mfr PN EB-4731	01121		3	

Ckt Ref	Description	Mfr	ESI Part No.	Qty Used	Recm SP
R_{11}	Res., Fxd, Comp., 1 meg ±10%, 1/2 w, Mfr PN EB-1051	01121		1	
R_{12}	Res., Fxd, Comp, 220K ±10%, 1/2 w, Mfr PN EB-2241	01121		3	
R_{13}	Res., Var, Comp, 250K ±10%, 2.25 w	01121	9128	1	
R_{14}	Res., Fxd, Comp, 10K ±10%, 1/2 w, Mfr PN EB-1031	01121		1	
R_{15}	Res., Fxd, Comp, 27K ±10%, 1/2 w, Mfr PN EB-2731	01121		1	
R_{16}	Res., Fxd, Comp, 100K ±10%, 1/2 w, Mfr PN EB-1041	01121		12	
R_{17}	Res., Fxd, Comp, 390K ±10%, 1/2 w, Mfr PN EB-3941	01121		2	
R_{18}	Same as R_{16}				
R_{19}	Res., Fxd, Comp, 330K ±10%, 1/2 w, Mfr PN EB-3341	01121		3	
R_{20}	Res., Fxd, Comp, 5.6K ±10%, 1/2 w, Mfr PN EB-5621	01121		3	
R_{21}	Same as R_{16}				
R_{22}	Res., Fxd, Comp, 22K ±10%, 2 w, Mfr PN HB-2231	01121		3	

Ckt Ref	Description	Mfr	ESI Part No.	Qty Used	Recm SP
R_{23}	Res., Fxd, Comp, 4.7K ±10%, 1/2w, Mfr PN EB-4721	01121		2	
R_{24}	Same as R_{16}				
R_{25}	Same as R_{17}				
R_{26}	Same as R_{20}				
R_{27}	Same as R_{19}				
R_{28}	Same as R_{16}				
R_{29}	Same as R_{22}				
R_{30}	Same as R_{8}				
R_{31}	Same as R_{12}				
R_{32}	Res., Fxd, Comp,1K ±10%, 1/2w, Mfr PN EB-1021	01121		2	
R_{33}	Res., Var, Comp, 500K ±30%, .1w	71590	9188	2	
R_{34}	Res., Fxd, Comp, 3.3K ±10%, 1/2w, Mfr PN EB-3321	01121		2	
R_{35}	Same as R_{19}				
R_{36}	Same as R_{8}				
R_{37}	Same as R_{16}				
R_{38}	Same as R_{22}				
R_{39}	Same as R_{16}				
R_{40}	Res., Fxd, Deposited Carbon, 27.5K ±1%, 1/2w, Mfr PN DC1-27.5K, 1/2w, ±1%	19701		3	

Ckt Ref	Description	Mfr	ESI Part No.	Qty Used	Recm SP
R_{41}	Res., Var, WW, 100K 1%, 3 w	12697	9111	3	
R_{42}	Res., Fxd, Deposited Carbon, 18K ±1%, 1/2 w, Mfr PN DC1-18K, 1/2 w, ±1%	19701		4	
R_{43}	Res., Var, Comp, 5K ±10%, 2 w	01121	9130	2	
R_{44}	Same as R_{42}				
R_{45}	Res., Fxd, Deposited Carbon, 500K ±1%, 1/2 w, Mfr PN DC1-500K, 1/2 w, ±1%	19701		12	
R_{46}	Res., Fxd, Deposited Carbon, 250K ±1%, 1/2 w, Mfr PN DC1-250K, 1/2 w, ±1%	19701		6	
R_{47}	Same as R_{45}				
R_{48}	Res., Fxd, Comp, 2.7 meg ±10%, 1/2 w, Mfr PN EB-2751	01121		3	
R_{49}	Same as R_{16}				
R_{50}	Res., Var, WW, 100K 1%, 3 w	12697	9118	1	
R_{51}	Same as R_{40}				
R_{52}	Same as R_{42}				
R_{53}	Res., Var, Comp, 5K 10%, 2 w	01121	9131	1	
R_{54}	Same as R_{42}				
R_{55}	Same as R_{45}				

Ckt Ref	Description	Mfr	ESI Part No.	Qty Used	Recm SP
R_{56}	Same as R_{48}				
R_{57}	Same as R_{46}				
R_{58}	Same as R_{45}				
R_{59}	Same as R_{10}				
R_{60}	Same as R_{10}				
R_{61}	Res., Fxd, Comp, 68K ±10%, 1/2 w, Mfr PN EB-6831	01121		1	
R_{62}	Same as R_{34}				
R_{63}	Same as R_{23}				
R_{64}	Res., Fxd, Comp, 680Ω ±10%, 1/2 w, Mfr PN EB-6811	01121		1	
R_{65}	Res., Var, WW, 100K 1%, 3 w	12697	9110	1	
R_{66}	Same as R_{40}				
R_{67}	Res., Fxd, Deposited Carbon, 20K ±1%, 1/2 w, Mfr PN DC1-20K, 1/2 w, ±1%	19701		2	
R_{68}	Same as R_{67}				
R_{69}	Same as R_{45}				
R_{70}	Same as R_{46}				
R_{71}	Same as R_{45}				
R_{72}	Same as R_{48}				
R_{73}	Same as R_{45}				

Ckt Ref	Description	Mfr	ESI Part No.	Qty Used	Recm SP
R_{74}	Same as R_{45}				
R_{75}	Same as R_{46}				
R_{76}	Same as R_{45}				
R_{77}	Same as R_{45}				
R_{78}	Same as R_{46}				
R_{79}	Same as R_{45}				
R_{80}	Same as R_{45}				
R_{81}	Same as R_{46}				
R_{82}	Same as R_{32}				
R_{83}	Res., Fxd, Comp, 270K ±5%, 1/2 w, Mfr PN EB-2741	01121		3	
R_{84}	Res., Var, Comp, 100K ±30%, .1 w, Mfr PN DC1-100K, 0.1 w, ±30%	71590		3	
R_{85}	Same as R_{20}				
R_{86}	Same as R_{23}				
R_{87}	Same as R_{16}				
R_{88}	Res., Fxd, Comp, 15K ±10%, 2 w, Mfr PN HB-1531	01121		1	
R_{89}	Same as R_{16}				
R_{90}	Same as R_{33}				
R_{91}	Res., Var, Comp, 100K ±10%, 2 w	01121	9129	1	

Ckt Ref	Description	Mfr	ESI Part No.	Qty Used	Recm SP
R_{92}	Same as R_{12}				
R_{93}	Res., Fxd, Comp, 1.5K ±10%, 1/2 w, Mfr PN EB-1521	01121		1	
R_{94}	Res., Fxd, Comp, 100Ω 10%, 1/2 w, Mfr PN EB-1011	01121		3	
R_{95}	Same as R_{16}				
R_{96}	Same as R_{16}				
R_{97}	Same as R_{11}				
R_{98}	Same as R_{11}				
R_{99}	Res., Fxd, WW, 400Ω ±5%, 5 w, Mfr PN AXIOHM 5XM	63743		1	
R_{100}	Same as R_{8}				
R_{101}	Same as R_{8}				
R_{102}	Res., Fxd, WW, 1Ω ±5%, 5 w, Mfr PN AXIOHM 5XM	63743		1	
R_{103}	Res., Fxd, WW, 100Ω ±5%, 5 w, Mfr PN AXIOHM 5XM	63743		1	
R_{104}	Res., Fxd, WW, 10K ±10%, 5 w, Mfr PN AXIOHM 5XM	63743		1	
R_{105}	Same as R_{83}				
R_{106}	Same as R_{84}				
R_{107}	Res., Fxd, Comp, 82K ±10%, 1 w, Mfr PN GB-8231	01121		2	

Ckt Ref	Description	Mfr	ESI Part No.	Qty Used	Recm SP
R_{108}	Res., Fxd, WW, 7K ±10%, 10w, Mfr PN AXIOHM 5XM	63743		1	
R_{109}	Same as R_{94}				
R_{110}	Res., Fxd, Comp, 2.2 meg ±10%, 1/2w, Mfr PN EB-2251	01121		2	
R_{111}	Same as R_{83}				
R_{112}	Same as R_{16}				
R_{113}	Same as R_{94}				
R_{114}	Same as R_{110}				
R_{115}	Res., Var, Comp, 100K Trim Pot	71590	9235	1	
R_{116}	Res., Fxd, Comp, 22Ω ±10%, 1w, Mfr PN GB-2201	01121		1	
R_{117}	Same as R_{107}				
R_{118}	Res., Fxd, Comp, 10K ±10%, 1/2w, Mfr PN EB-1031	01121		1	
RT_1	Thermistor, 100K	02114	9214	1	
RT_2	Thermistor, 6.8K	02114	9213	1	
S_1	Switch, Toggle SPDT, Mfr PN L62D	73586		2	
S_2	Same as S_1				
S_3	Switch, Rotary, 2 Section, 8 position	76854	9123	1	
S_4	Switch, Rotary, 2 Section, 3 position	76854	9119	1	

Ckt Ref	Description	Mfr	ESI Part No.	Qty Used	Recm SP
S_5	Switch, Rotary, 6 Section, 3 position	76854	9121	1	
S_6	Switch, Rotary, 3 Section, 3 position	76854	9120	1	
S_7	Switch, Rotary, 1 Section, 4 position	76854	9124	1	
T_1	Transformer, Power	11837	9186	1	
T_2	Transformer, Output	11837	9189	1	
	MISCELLANEOUS				
	Knob, Sensitivity, fine	11837		1	1
	Knob, Sensitivity, coarse	11837		1	1
	Knob, Selectivity	11837		1	1
	Knob, Fine tuning	11837		1	1
	Knob, Frequency	11837		1	1
	Knob, Range	11837		1	1
	Knob, Power	11837		1	1
	Knob, Impedance	11837		1	1
	Dial, Frequency	11837	9234	1	1
V_1	Tube, 7308	73445		1	1
$V_{2,3,4,6}$	Tube, 6BL8	73445		4	2
$V_{5,7,8,9}$	Tube, 6BM8	73445		4	2

NOVEMBER 1966

ESI® INSTRUCTION MANUAL CHANGES

Model 861A AC Generator-Detector

Instruction Manual dated July 1964

1. Page 2.6-2, subsection 2.6.3: Delete the paragraph on page 2.6-2 and replace it with the following:

   External line-operated equipment connected to the SYNC OUT or DET OUT terminals may cause ground loops. If ground loops become a problem, it may be possible (electrical codes permitting) to isolate the Model 861A or the external equipment from the power line ground. The Model 861A has an isolation transformer built in to the power-line input, and is well isolated from ground when the three-pin connector is plugged into a two pin adapter. Multipath grounding should be avoided, but there should be at least one connection from the chassis to ground.

2. Figure 4.2, sheet 2, Detector Schematic: Change tube type of V2, V3, V4, and V6 from 6BL8 to 7643.

3. Page 4.3-17, next-to-last line from bottom: Change entry from "Tube, 6BL8" to "Tube, 7643".

Part No. 9103-2

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Electro Scientific Industries
7524 S. W. MACADAM AVE. • PORTLAND 19, OREGON

VOLTAGE
DIVIDERS

APRIL 1963

MODEL

DT 72A

Instruction Manual

DECADE
TRANSFORMER

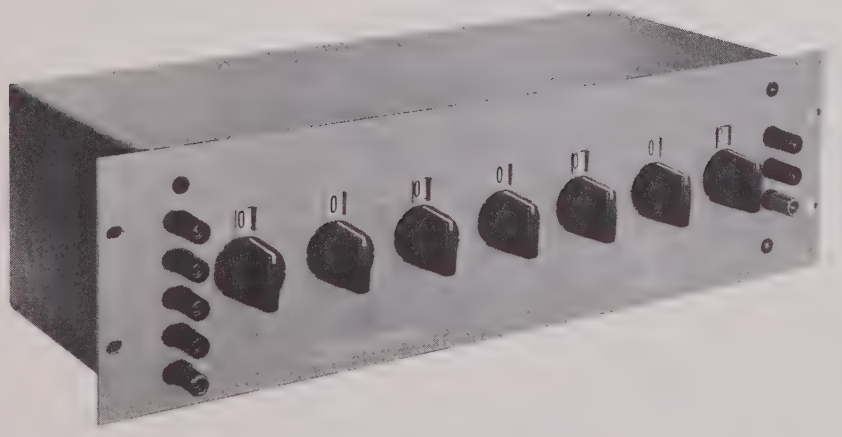

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TABLE OF CONTENTS

I INTRODUCTION

1.1 DESCRIPTION
1.2 FEATURES
1.3 SPECIFICATIONS

II OPERATION

2.1 VOLTMETER CALIBRATION
2.2 AMMETER CALIBRATION
2.3 VOLTAGE DIVIDER CALIBRATION
2.4 TRANSFORMER RATIO CALIBRATION
2.5 IMPEDANCE COMPARISON MEASUREMENTS

2.5.1 CAPACITANCE COMPARISONS

III THEORY

3.1 SOURCES OF ERROR
3.2 LOADING EFFECTS

IV MAINTENANCE

V PARTS LIST

SECTION I

INTRODUCTION

1.1 DESCRIPTION

The MODEL DT 72A DEKATRAN DECADE TRANSFORMER is a laboratory standard divider for establishing either voltage or current ratios at audio frequencies.

The DEKATRAN circuit is an auto-transformer with a variable tap. The tap position is indicated by the dial reading which gives the ratio of output turns to input turns. Additional windings extend the ratio above and below the input so that voltage ratios of -0.1 and +1.1 are available.

The accuracy of the DEKATRAN is established by intercomparisons over a wide range of frequencies and dial settings, traceable to a special NBS - certified transformer.

1.2 FEATURES

The inherent stability of the DEKATRAN assures permanent calibration over wide ranges of ambient temperatures, humidity, vibration, and shock. No special input voltage values are required for specified accuracy within the limits shown under "Maximum Voltage".

A 10% overwinding and a 10% underwinding on the first decade are brought out to terminals on the front panel. These terminals provide a convenient source for obtaining at 10:1 ratio for bridge type measurements. They are also a convenient source for driving a phase shifting network, especially when comparing values near the end of the scale.

The decade dials indicate the output voltage as a decimal part of the input. The output can be read to seven significant digits. The first dial has end stops to prevent accidental switching from zero to full output. Each of the other dials rotates continuously, with no end stops, minimizing setting time. Also, a 10% range overlap is provided on both ends of each decade except the first, reducing the number of individual dial adjustments necessary for null balance measurements.

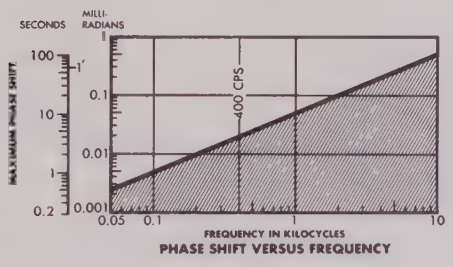
As dial settings are being changed, switching transients are minimized by a special circuit which couples the adjacent voltage steps through a resistor while the switching is taking place.

The high input impedance of the DEKATRAN divider makes it well suited for use in high impedance circuits without causing excessive loading.

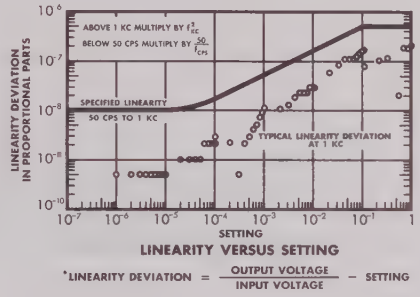
1.3 SPECIFICATIONS

LINEARITY AND PHASE SHIFT

The terminal linearity and phase shift of the DEKATRAN depend on the dial setting and the frequency. The specified values of these quantities for the MODEL DT 72A are shown in the curves below.



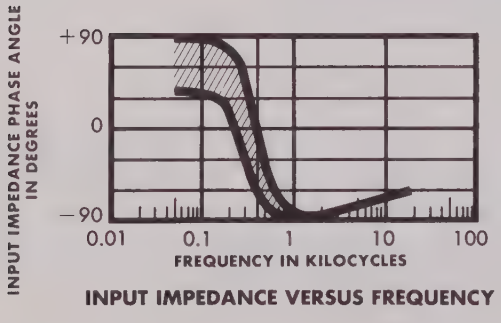
PHASE SHIFT VERSUS FREQUENCY


ABOVE 1 KC MULTIPLY BY f^2_{KC}
BELOW 50 CPS MULTIPLY BY $\frac{50}{f_{CPS}}$
SPECIFIED LINEARITY
50 CPS TO 1 KC
TYPICAL LINEARITY DEVIATION AT 1 KC
LINEARITY DEVIATION IN PROPORTIONAL PARTS
SETTING
LINEARITY VERSUS SETTING

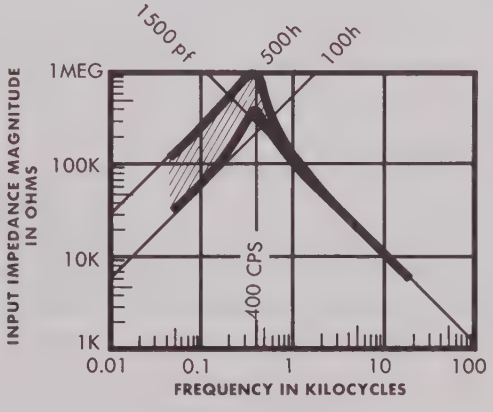
*LINEARITY DEVIATION = $\frac{\text{OUTPUT VOLTAGE}}{\text{INPUT VOLTAGE}}$ − SETTING

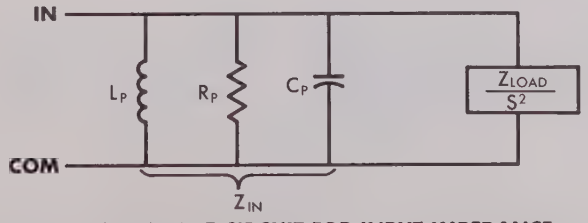
INPUT IMPEDANCE

With no output load the DEKATRAN has a high input impedance. This can be represented by the equivalent circuit shown below. A typical range of measured values for various dial settings and voltages is shown by the curves. When a load is connected to the output it is reflected to the input divided by the square of the DEKATRAN setting.



INPUT IMPEDANCE VERSUS FREQUENCY

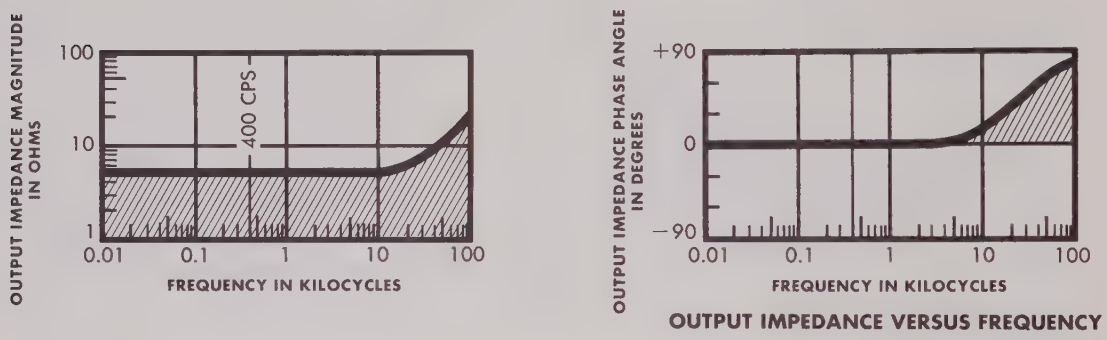




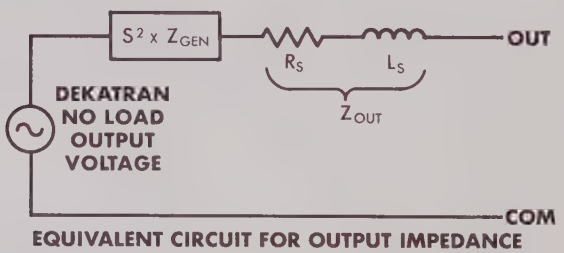
EQUIVALENT CIRCUIT FOR INPUT IMPEDANCE

OUTPUT IMPEDANCE

The DEKATRAN output impedance can be represented by the equivalent circuit shown below. Maximum values of the output impedance of the DEKATRAN alone are shown by the curves. In addition, any impedance in the source to which the unit is connected will be reflected to the output multiplied by the square of the DEKATRAN setting.



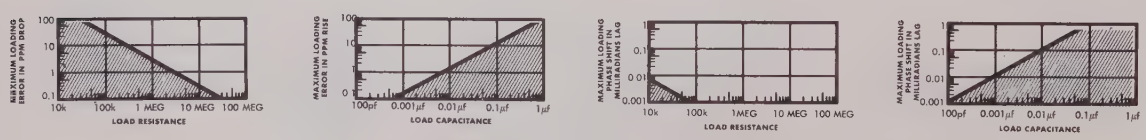
OUTPUT IMPEDANCE VERSUS FREQUENCY



EQUIVALENT CIRCUIT FOR OUTPUT IMPEDANCE

OUTPUT LOADING

When a load is connected to the output of the DEKATRAN the output accuracy and phase shift are affected. The resulting values will depend on dial setting, frequency, and the type of load. At a frequency of 400 cps, typical maximum changes for resistive and capacitive loads are shown below.



EFFECTS OF LOAD RESISTANCE AND CAPACITANCE AT 400 CPS

Terminal Linearity:	50 cps to 1 kc: For settings 0.1 to 1.0: ±0.5 ppm For settings 0 to 0.1: $\pm(0.5\ (10 \times \text{setting})^{\frac{1}{2}} + 0.01$ ppm Above 1 kc: Multiply by F^2kc Below 50 cps: Multiply by 50/F cps
Resolution:	0.1 ppm (0.00001%) of input.
Range:	-0.0111111 to + 1.1111110.
Maximum Phase Shift:	(0.05 x fkc) milliradians for settings above 0.1.
Maximum Input Voltage:	(0.35 x f cps) volts rms; 350 volts maximum.
Maximum Output Current:	1 ampere.
Recommended Frequency Range:	50 to 10,000 cps.
Switching Transient Suppression:	Resistive contact to adjacent voltage steps maintained during switching.
Maximum DC Input:	For best performance no dc current should be permitted. A dc input of 20 microamperes will decrease the ac input voltage rating about 10% and increase distortion slightly; 200 microamperes will cause near-saturation of the core and serious errors.
Maximum Input Inductance:	Approximately 100 to 400 henrys depending on excitation.
Maximum Output Impedance:	Approximately 5 ohms in series with 30 microhenrys.
Readout:	Seven place, in-line.
Certificate:	Price includes an ESI certificate traceable to the National Bureau of Standards giving readings for each step of the first three decades.

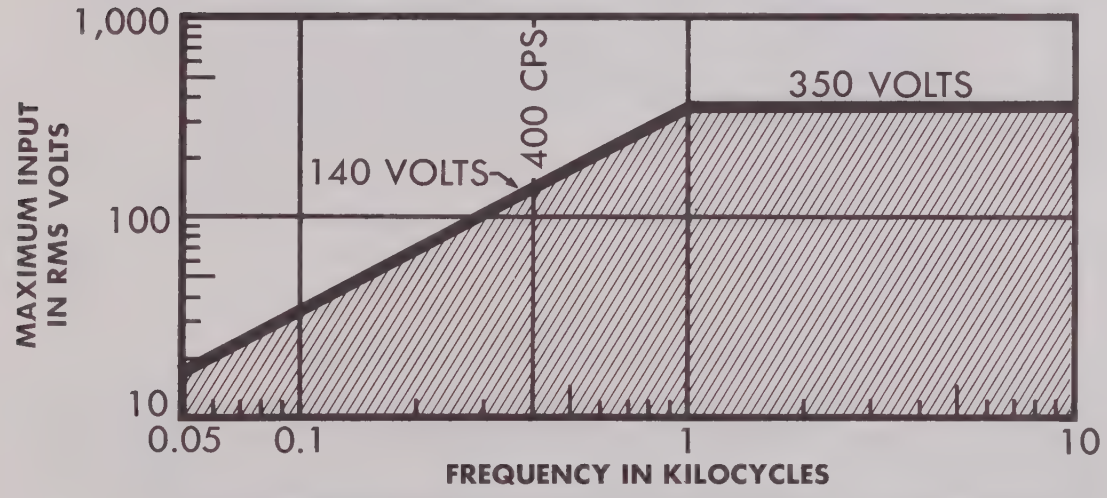
Dimensions and Mounting:	Front panel 5-1/4" high x 19" long; designed for standard rack mounting. Depth behind panel approximately 7-1/4".
Weight:	18 pounds net, 24 pounds packed for shipment.

SECTION II

OPERATION

The DEKATRAN transformer is almost always used in one of the following applications; to calibrate voltmeters, to calibrate ammeters, to calibrate voltage dividers, for transformer ratio measurements, or for impedance comparison measurements. The instructions in this section provide the basic information necessary to perform these measurements. If more information is desired, consult the THEORY section.

CAUTION: In all applications the maximum current at any terminal should not exceed 1 ampere, and the voltage should be limited as shown in the following graph:



MAXIMUM INPUT VOLTAGE VERSUS FREQUENCY

2.1 VOLTMETER CALIBRATION

The circuit diagram and interconnection wiring diagram for voltmeter calibration are shown in Figure 2.1a. The isolation transformer is used to prevent power line coupling between the generator and the voltmeter. V_1 may be either the calibrated or uncalibrated voltmeter. The equation relating the two voltmeter readings is:

$$V_2 = (V_1)(\text{dial setting})$$

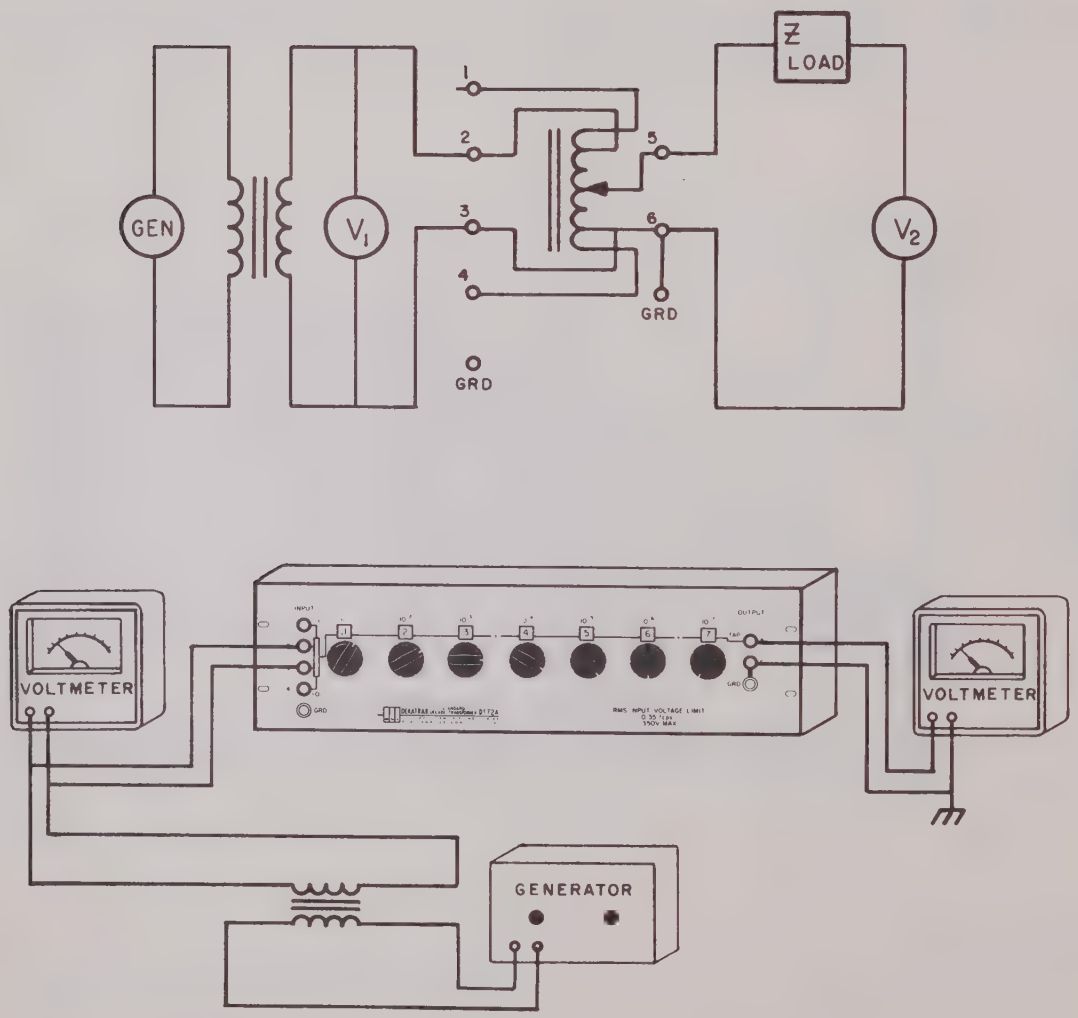


FIG. 2.1a

The only requirement of the circuit is that load impedance (impedance of the voltmeter) be of a sufficient magnitude, so as not to load the transformer. Whether or not the load impedance can be neglected depends on the degree of accuracy desired. The graph in Figure 2.1b gives the maximum load resistance error in ppm drop for load resistances from 10k to 100 meg.

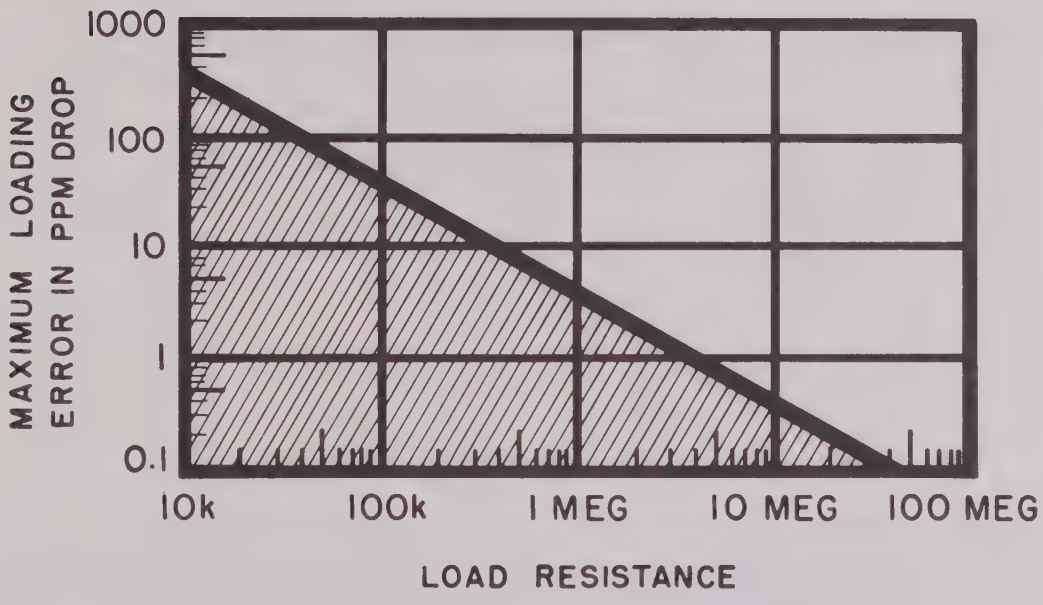


FIG. 2.1b

(continued next page)

If the loading error is excessive then the load current must be isolated from the decade transformer. This is accomplished by using a second divider as shown in Figure 2.1c to carry the current. This second divider does not have to be calibrated. The desired ratio is then set on the calibrated divider dials and the uncalibrated divider is adjusted for a null reading on the detector. The equation relating the two voltmeter readings is:

$$V_2 = (V_1)(\text{dial setting})$$

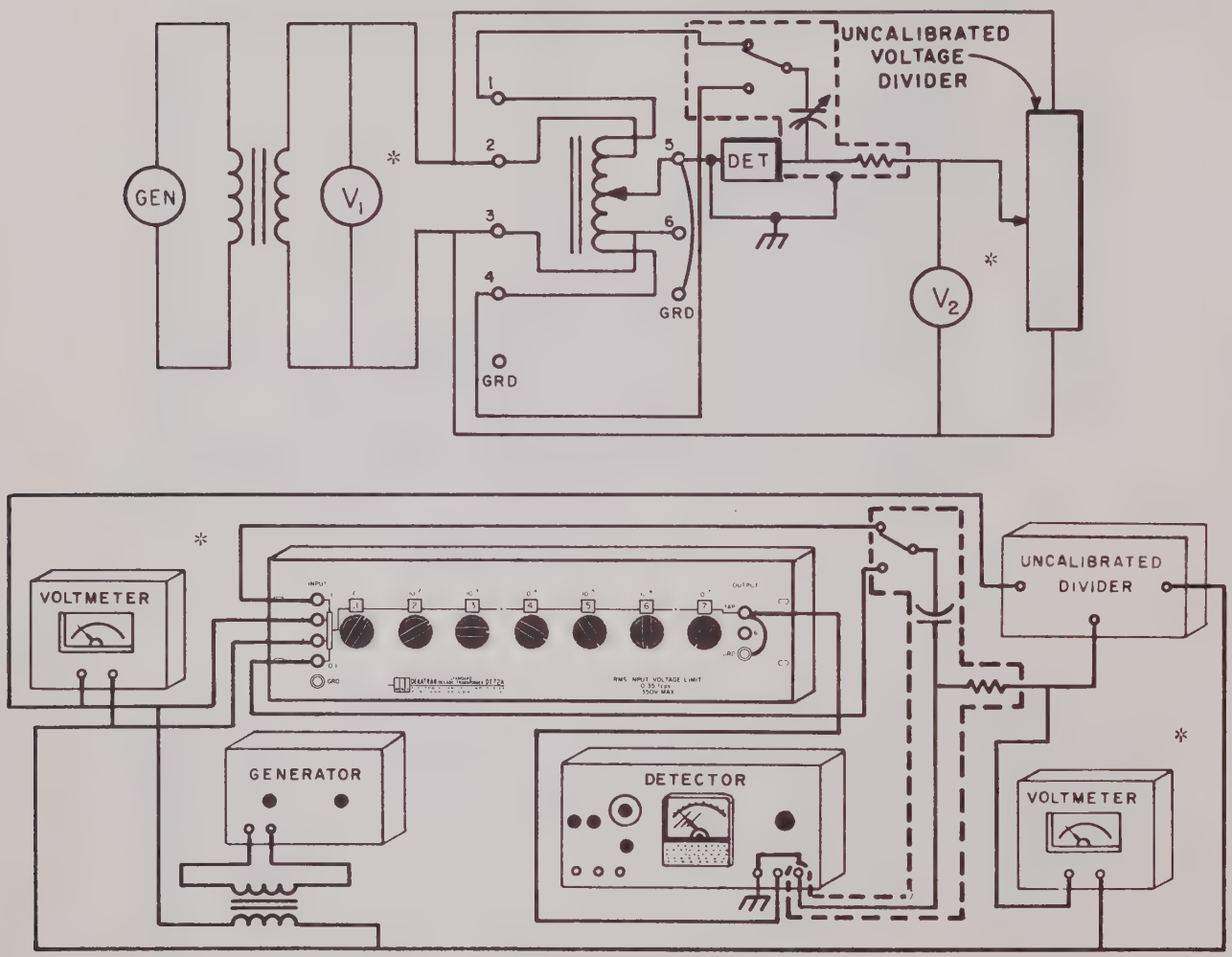


FIG. 2.1c

Phase compensation may be necessary to reach a null balance, particularly at higher frequencies. The switchable capacitor in Figure 2.1c shows the most common method of phase compensation for this circuit. Typical values for the resistor-capacitor combination are 3 kilohms and 0-1000pf.

*If voltmeters are grounded, detector must be isolated from ground.

2.2 AMMETER CALIBRATION

When the DT 72A is used as a current divider, a current generator and ammeter are connected to terminals 5 and 6, marked "OUTPUT". The circuit diagram and interconnection wiring diagram for ammeter calibration are shown in Figure 2.2a. The equation relating the two ammeter readings is:

$$A_1 = (A_2)(\text{dial setting})$$

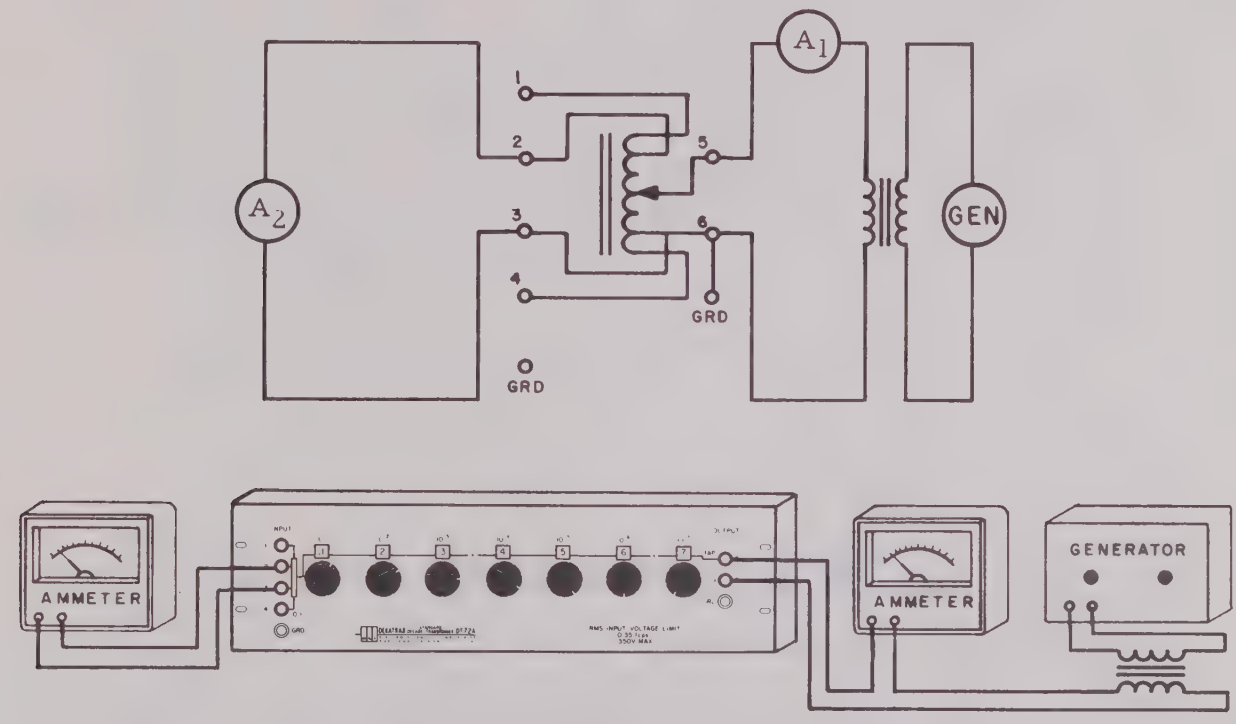


FIG. 2.2a

In current divider applications a negligible voltage should appear across the input impedance of the DEKATRAN. The graph in Figure 2.2b gives the error due to the impedance of the ammeter for ammeter resistances from 10 milliohms to 100 ohms.

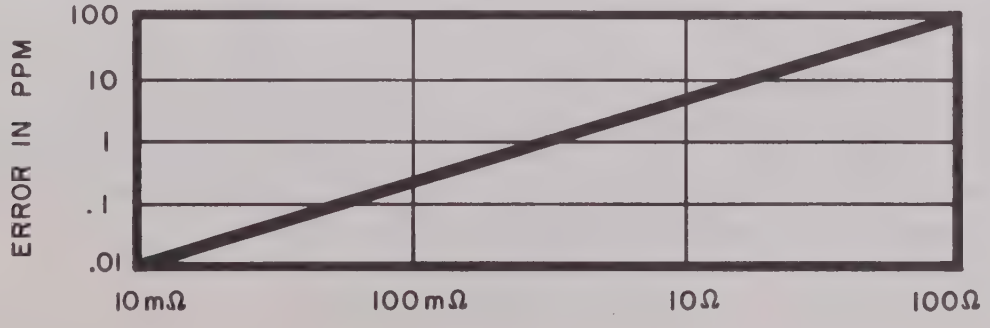


FIG. 2.2b

If the error is excessive then the load voltage drop must be separated from the voltage drop across the transformer. This is done by using a second divider as shown in Figure 2.2c. This second divider does not have to be calibrated. It balances out the voltage drop across the calibrated transformer.

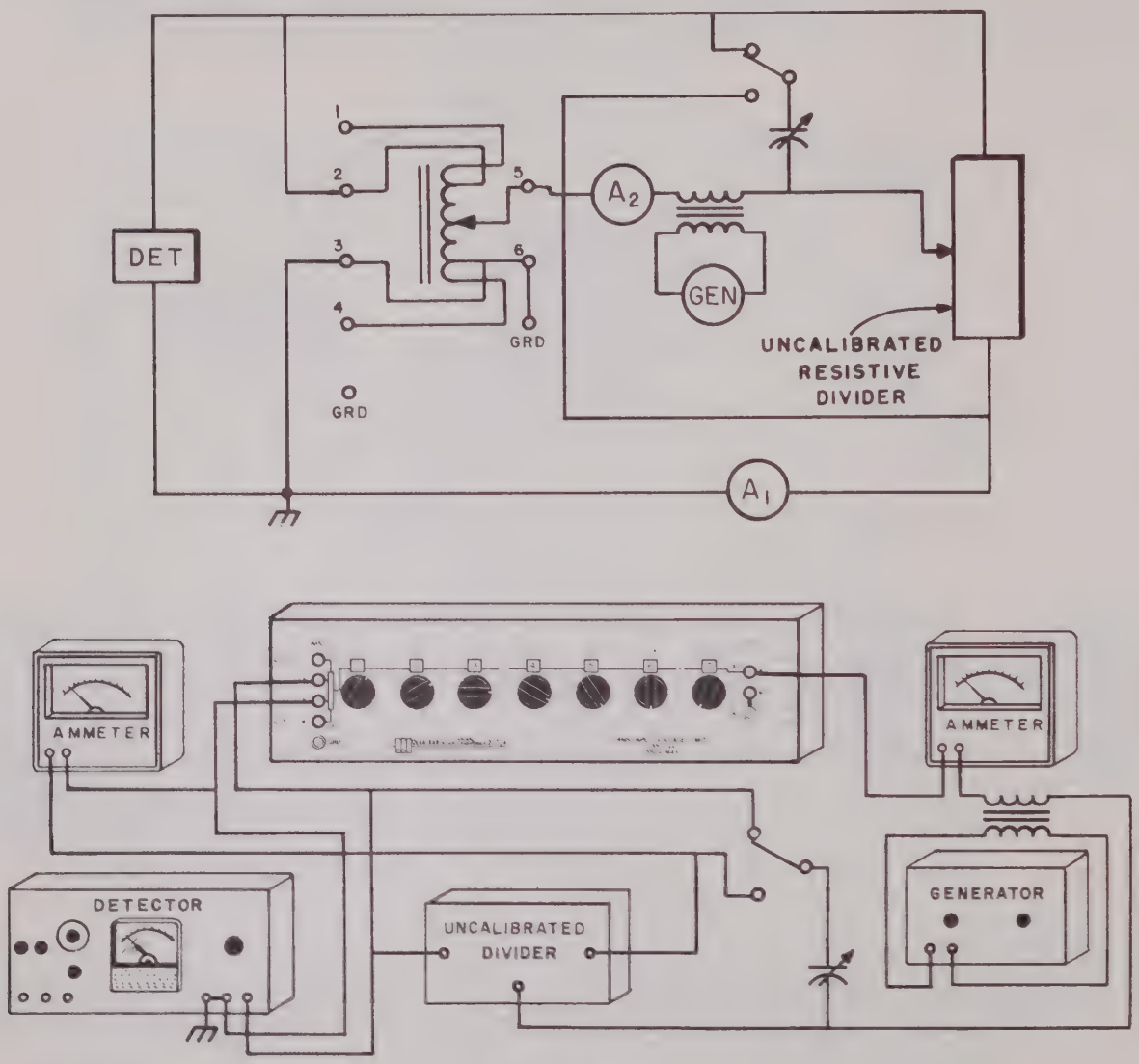


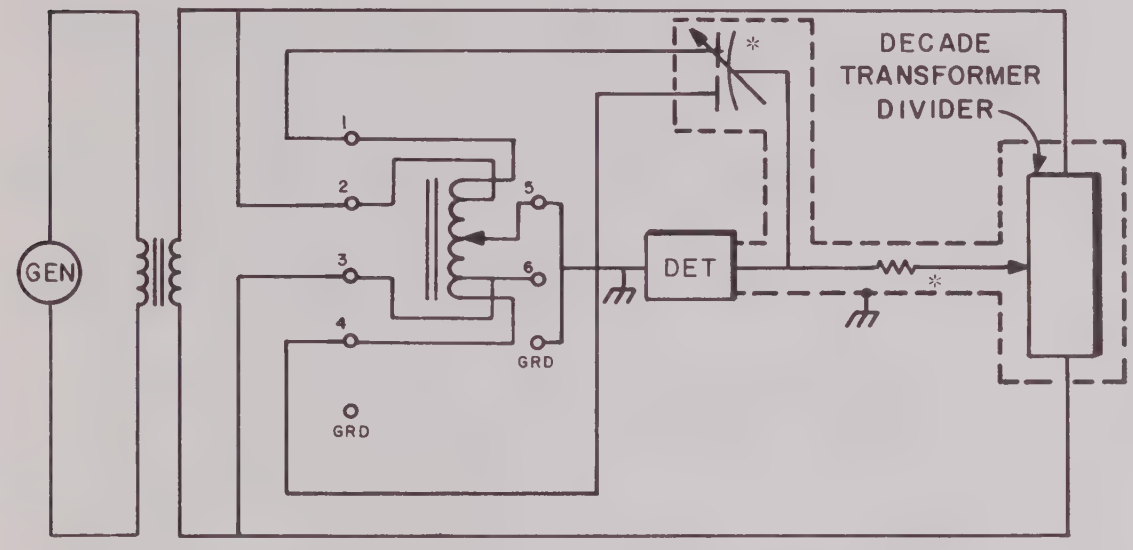
FIG. 2.2c

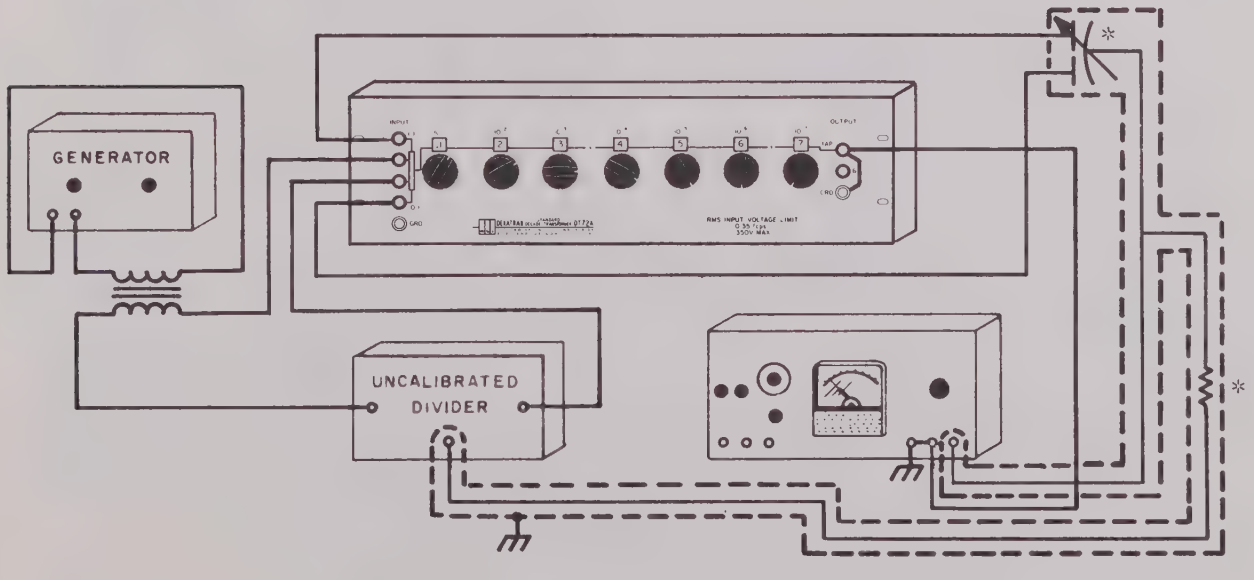
The desired ratio is set on the dials of the DT 72A and the uncalibrated divider is adjusted for a null reading on the detector. The switchable capacitor (typically 0-1000pf) is for phase compensation and may be needed to obtain a null balance, particularly at higher frequencies. When a null balance is reached the equation relating the two ammeter readings is:

$$A_1 = (A_2)(\text{dial setting})$$

2.3 VOLTAGE DIVIDER CALIBRATION

A decade transformer is frequently used to calibrate another decade transformer or for ac calibration of a resistive decade divider as shown in Figures 2.3a and 2.3b.





* TYPICAL VALUES; 50pf AND 3 KILOHMS

FIG. 2.3a

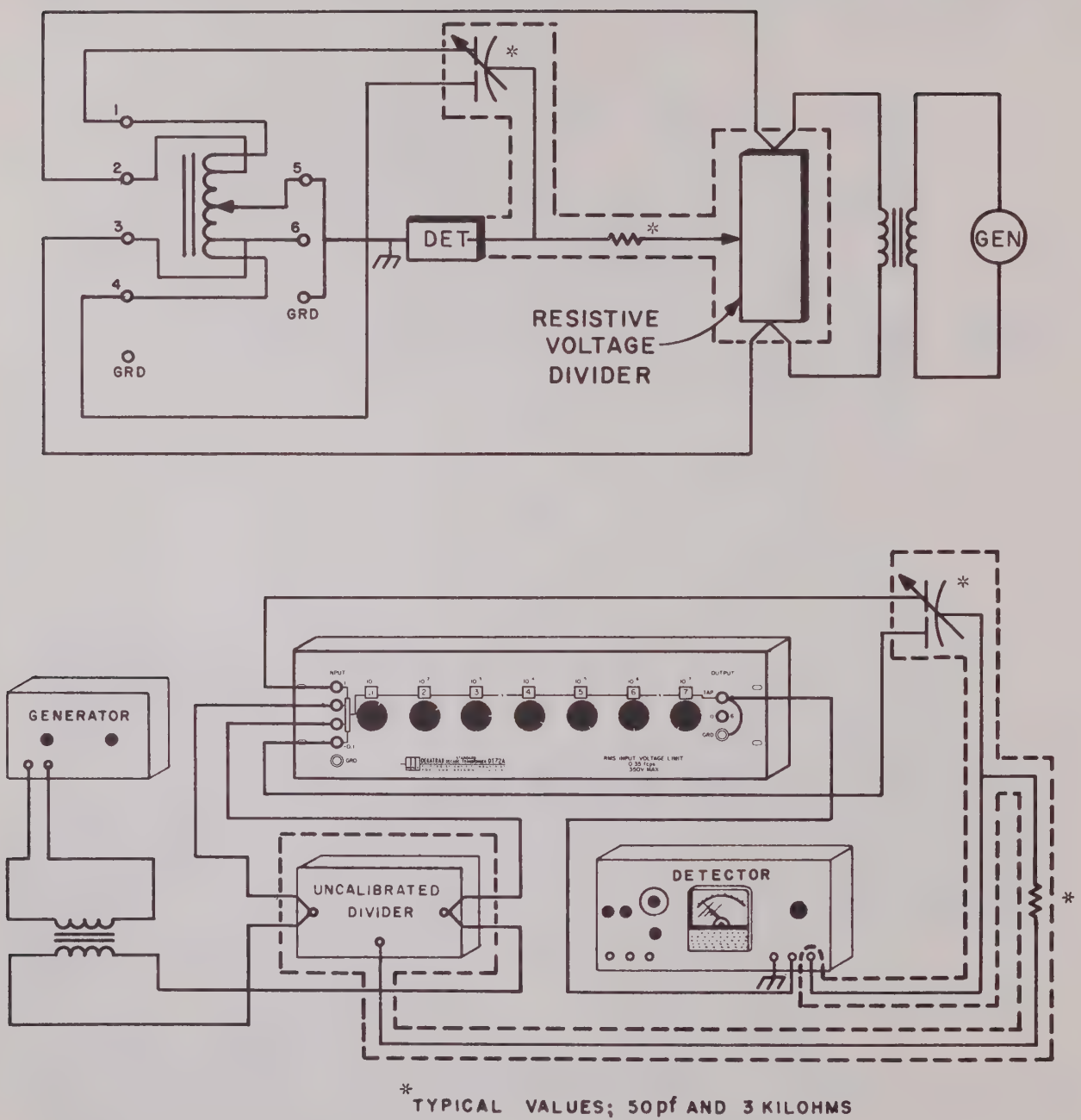

1
2
3
4
5
6
GRD
GRD
DET
*
*
RESISTIVE
VOLTAGE
DIVIDER
GEN
GENERATOR
UNCALIBRATED
DIVIDER
DETECTOR
*
*
*TYPICAL VALUES; 50pf AND 3 KILOHMS

FIG. 2.3b

In the circuit shown in Figure 2.3a a differential capacitor is used to adjust for any phase difference between the two dividers. Resistance is added in series with the tap of the divider being calibrated, as shown, so that its output resistance will be much larger than its reactance. The differential capacitor is connected from the detector end of the resistor to the overwindings of the DT 72A. This capacitance is used to draw a small amount of current through the resistor which in turn causes a small quadrature voltage drop across the resistor. If this voltage is extremely small in comparison to the total voltage across the dividers, it can be considered as being quite accurately in quadrature and will have a negligible effect on the magnitude calibration.

If a large difference in phase is to be corrected, care must be taken to see that the current through the resistance is exactly at right angles to the applied voltage. Any phase difference from 90° in the current through the resistor will cause a voltage drop in phase with the transformer voltage being calibrated, and will affect the magnitude ratio measurement.

The circuit used for the calibration of resistive dividers, shown in Figure 2.3b, is very similar to the transformer divider calibration circuit. However, in the case of the resistive divider the resistance is added in series with the tap of the divider to provide an output resistance when the divider tap is near its end points.

Usually, very sensitive detectors must be operated with one of their two terminals grounded to prevent stray pickup at their input terminals. In Figures 2.3a and 2.3b the grounded side of the detector is connected to the tap of the DT 72A. This places stray capacitance to ground either across the detector or across the low impedance transformer arms.

If the DT 72A dial settings at the end point null adjustments differs from 0.000,000,0 and 1.000,000,0 it will sometimes be necessary to make a correction for all dial settings. This can be most easily accomplished by a simple linear interpolation. By plotting the end point errors on a graph and connecting these two points with a line as shown below, the error at any dial setting may be determined by inspecting the graph. An example is given in Figure 2.3c.

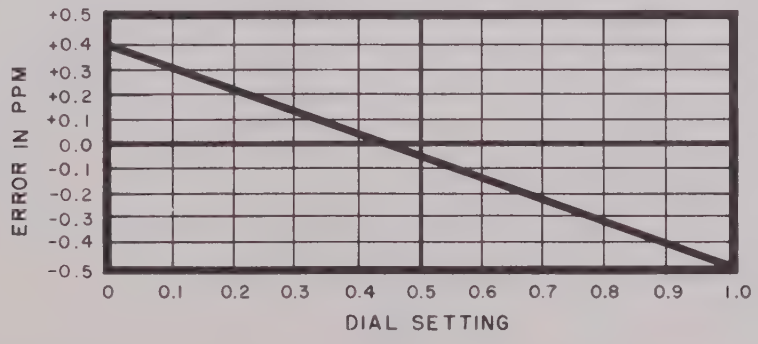
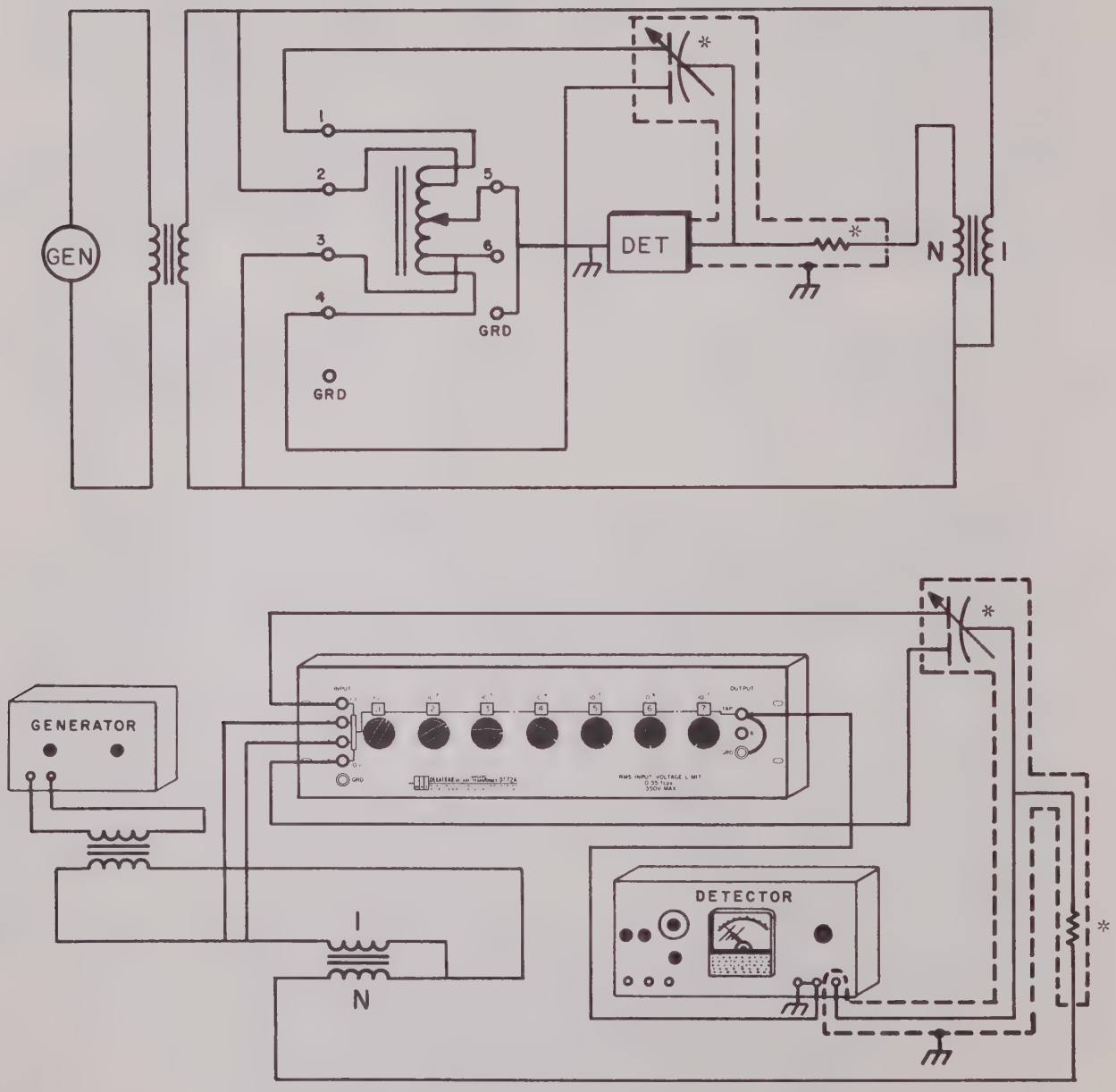


FIG. 2.3c

2.4 TRANSFORMER RATIO CALIBRATION

The circuit used for step-down transformer calibration, shown in Figure 2.4a, is essentially the same circuit as that used for the calibration of a decade divider. The calibration procedure is discussed in Section 2.3.



*TYPICAL VALUES; 50pf AND 10KILOHMS

FIG. 2.4a

When calibrating a step-up transformer the first circuit cannot be used since the DT 72A would have to be operated at a ratio equal to or greater than 1.0.

A circuit which is suitable for the calibration of step-up transformers with ratios of 10:1 or less is shown in Figure 2.4b. The equivalent series impedance of the -0.1 overwinding of the DT 72A is approximately 0.5 ohm. Consequently, if the load due to the impedance of the transformer being calibrated is 500k or more, the error due to loading will be less than 1 ppm. Load impedances which are less than 500k may cause some significant error and therefore this error should be calculated or determined empirically by adding an equivalent load in parallel with the transformer being calibrated and noting the resulting equivalent error. The balance equation for this circuit is:

$N = 10 (S + .1) = 10S + 1$ where S = dial setting of DT 72A

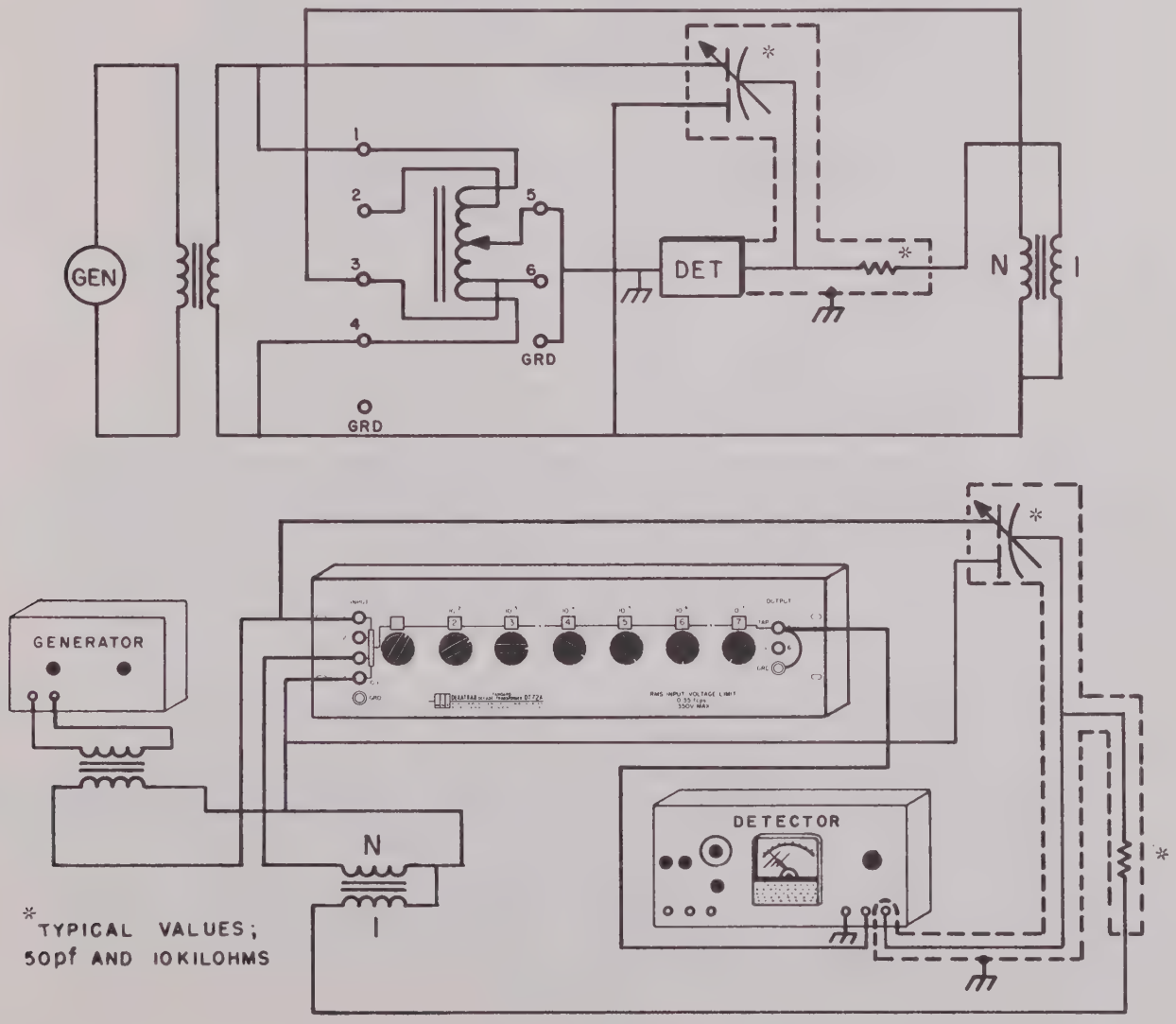


FIG. 2.4b

2.5 IMPEDANCE COMPARISON MEASUREMENTS

The DT 72A can be used to read the voltage ratio of two similar impedances as shown in Figure 2.5a.

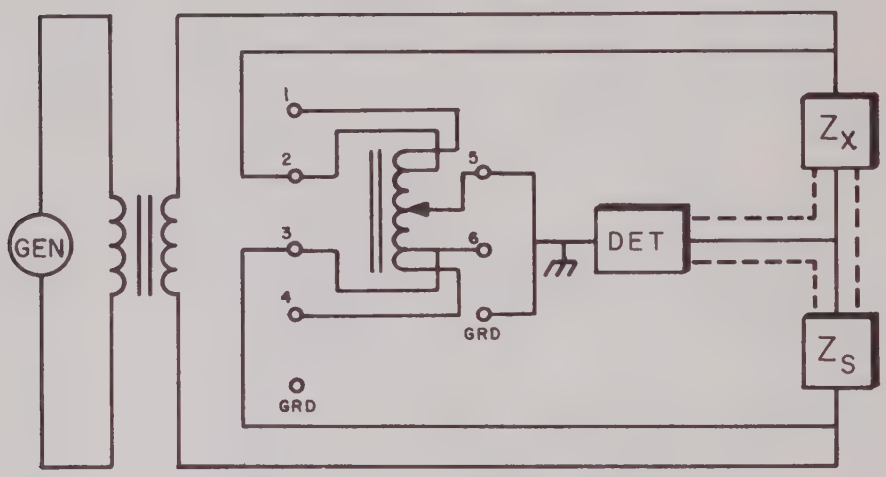


FIG. 2.5a

The voltage across the two series connected impedances are in the same ratio as the impedances. Therefore, a DT 72A can be used to compare a known impedance with an unknown impedance, the unknown impedance being equal to:

$$Z_x = \frac{(1 - S)}{S} \quad Z_s = \left(\frac{1}{S} - 1\right) Z_s$$

Where Z_s is the known impedance and S is the setting of the DT 72A at balance.

The phase balance of impedance bridges may be provided as a part of the unknown or standard impedance or as a quadrature voltage added in series with one of the taps of the DT 72A. If the phase balance is accomplished by an element (Z_p) in series with the impedance, care must be taken to keep the

capacitance from the junction to ground to a minimum, maximizing Z_L (see Figure 2.5b).

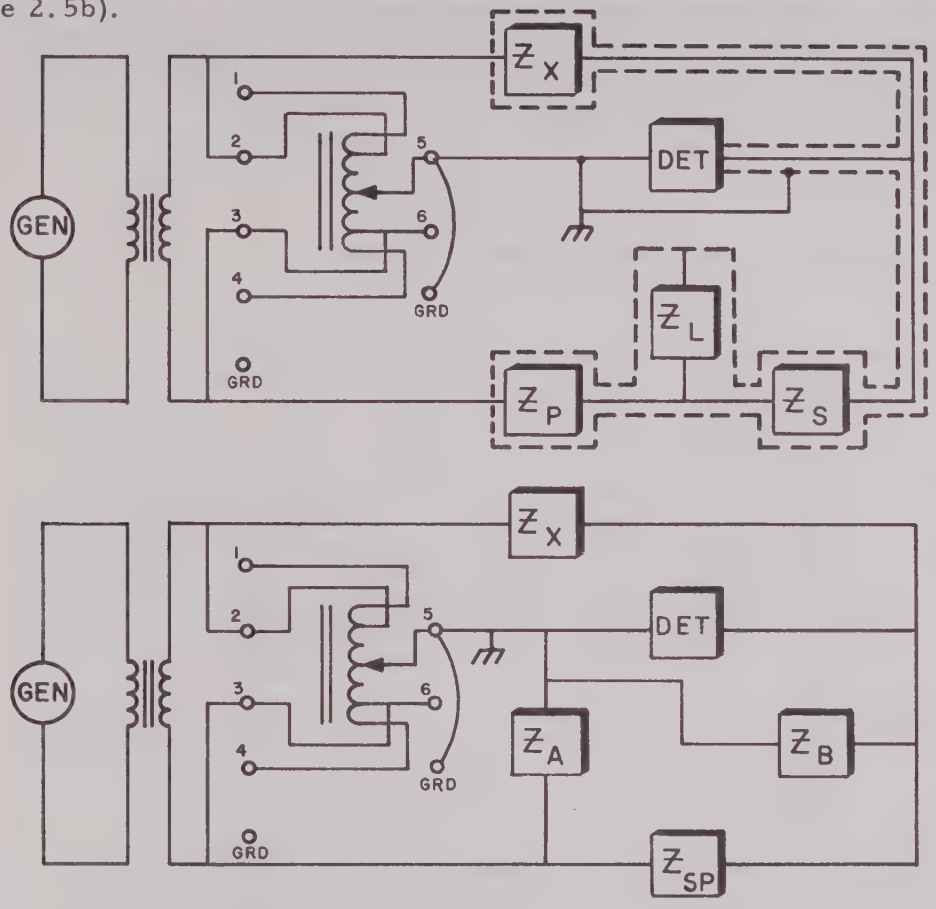


FIG. 2.5b

By means of a wye to delta transformation it can be seen that the only impedance of interest is Z_{sp}. Since Z_b is across the detector it will not affect the measurement accuracy. Z_A is across a low impedance transformer arm and can be neglected for all reasonable leakage impedances. From the transformation we get

$$Z_{sp} = Z_s + Z_p + \frac{Z_s Z_p}{Z_L}$$

where $\frac{Z_s Z_p}{Z_L}$ is the error term introduced by Z_L.

Additional information on this topic is given in the two papers, "A Ratio Transformer Bridge for Standardization of Inductors and Capacitors" and "Calibration of a Decade Transformer Having One ppm Linearity" at the end of this manual.

The calculations for the unknown impedance using the circuit shown in Figure 2.5a are somewhat laborious since the inverse of the DT 72A setting must be calculated. By utilizing the overwinding on the DT 72A as shown in Figure 2.5c with high unknown impedances, the impedance ratio calculation is reduced to a simple decimal point shift.

$$Z_x = 10\ (S)\ Z_s$$

where S is the DT 72A dial reading.

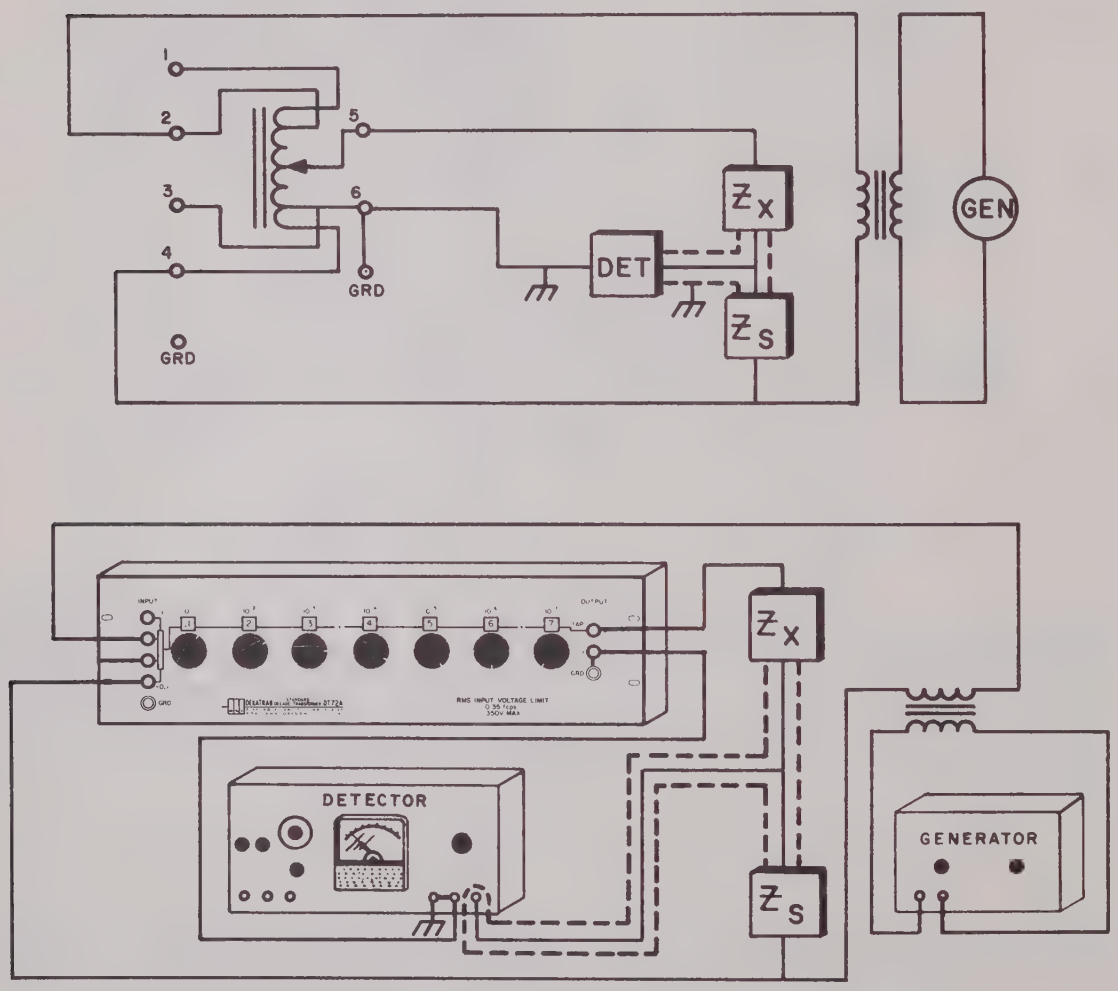


FIG. 2.5c

A second alternative method which is suited for 10:1 ratio, low impedance comparisons is shown in Figure 2.5d. In this circuit the power to the unknown and standard impedances is supplied directly from the generator and will not load the transformer. At low settings on the DT 72A, the unused upper winding will cause loading, resulting in errors. Therefore, the decade transformer should be operated between settings of 0.9 and 1.1 for highest accuracy. The impedance ratio equation is

$$Z_x = 10\,(S)\,Z_s$$

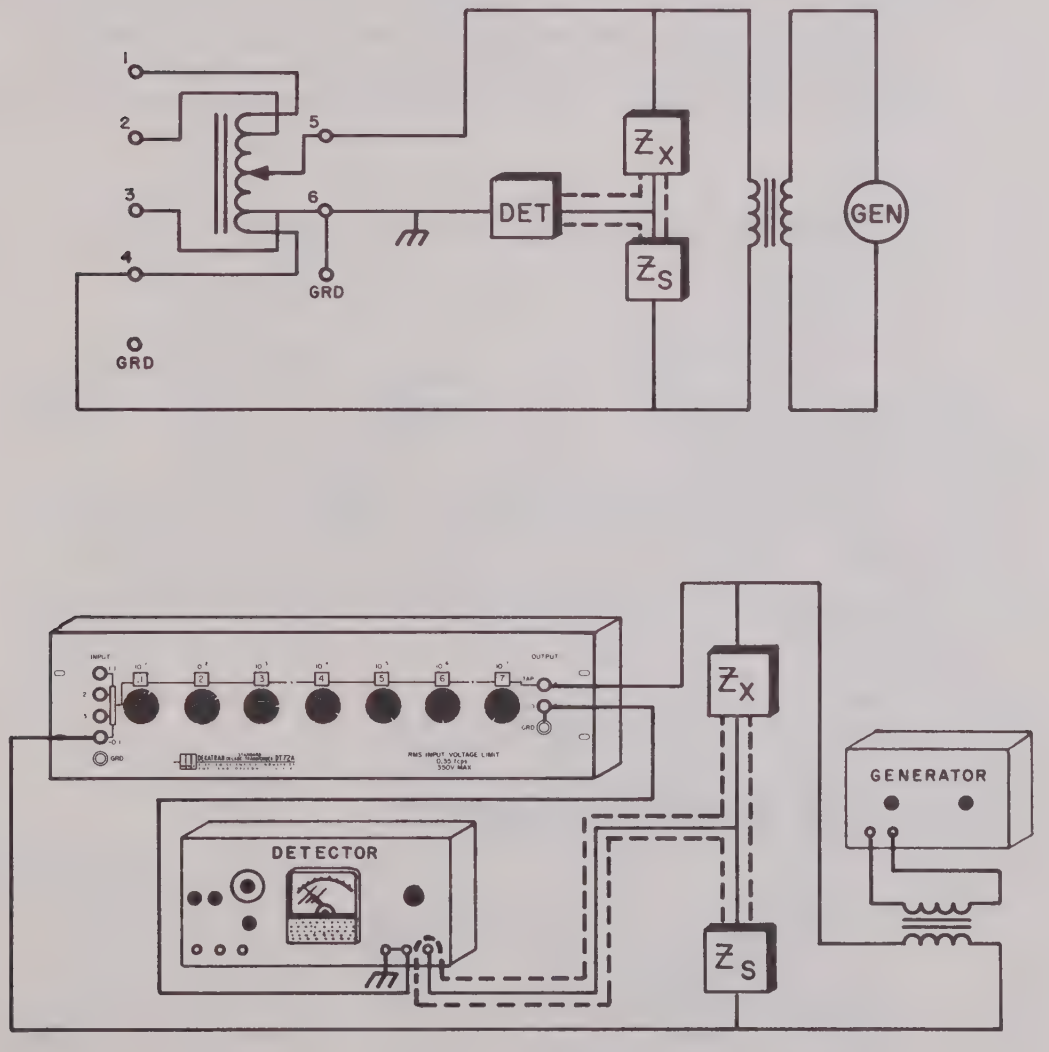


FIG. 2.5d

2.5.1 CAPACITANCE COMPARISONS

The circuits outlined thus far have only explained the basic principles of impedance comparisons. This section will discuss the details of devising circuits to make accurate capacitance measurements.

THREE TERMINAL CAPACITORS

Figure 2.5e shows the connections for the measurement of a three-terminal capacitor. With this circuit one of the stray capacitances is across the detector where it will affect only the sensitivity. The other stray is across a low impedance transformer winding which will not be noticably affected by the loading of reasonable values of stray capacitance. The two capacitors being compared are brought into angle balance by a "D" control in the standard capacitor arm.

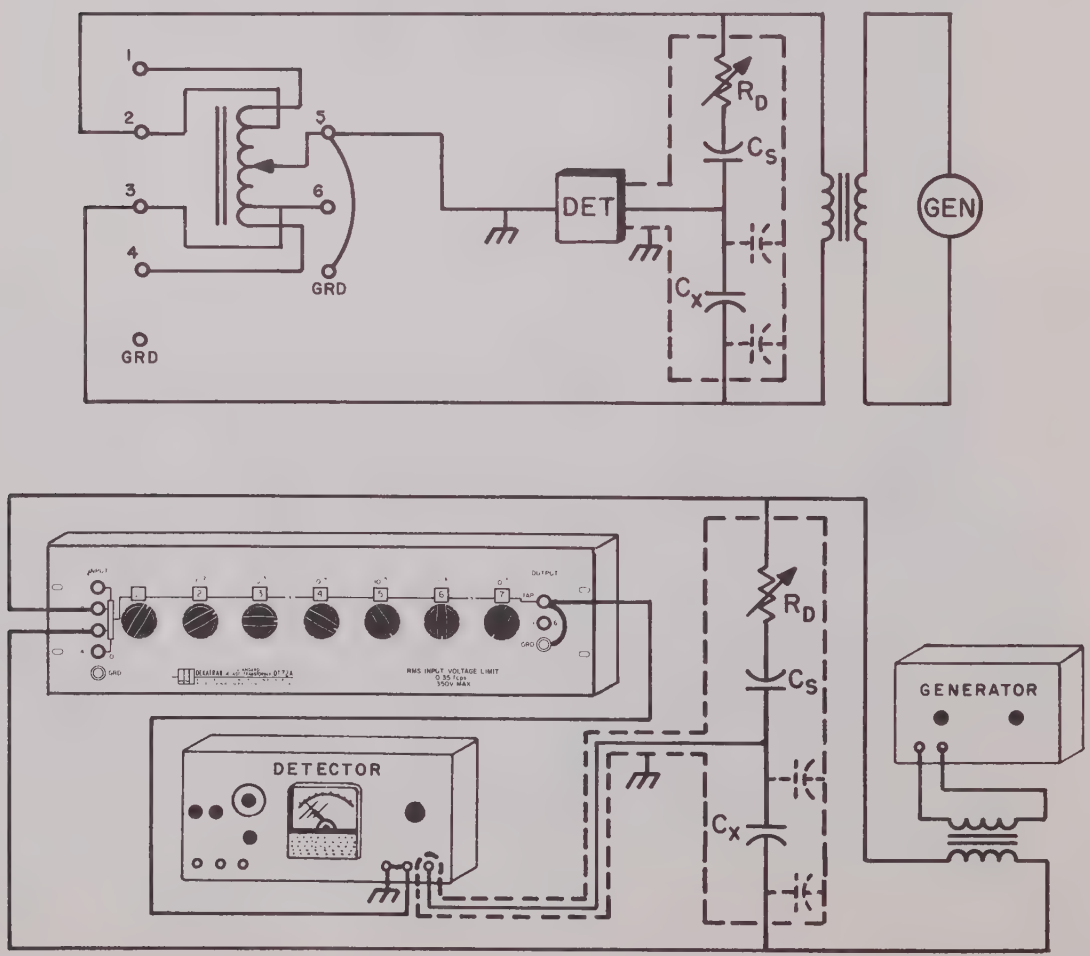
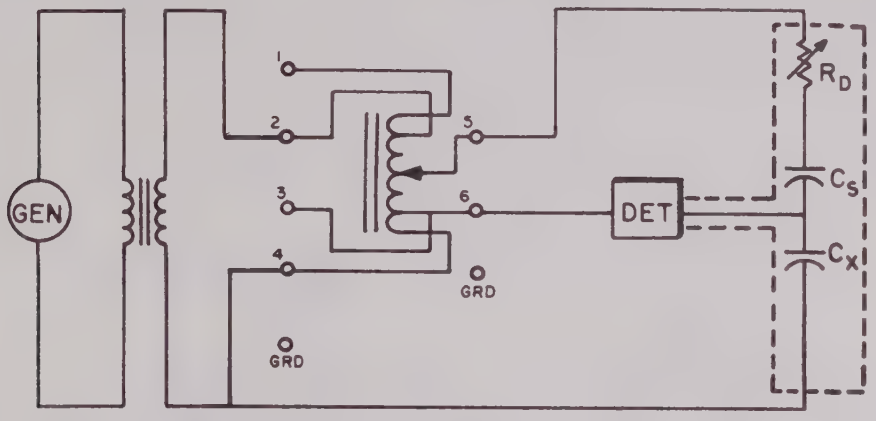


FIG. 2.5e

LOW VALUE CAPACITORS

When measuring a low value capacitor the circuit in Figure 2.5f should be used. Current is supplied to the capacitors from the transformer. With sufficiently high impedance capacitors the loading error can be neglected.

$C_x = 10\ (S)\ C_s$ where S is the DT 72A dial setting



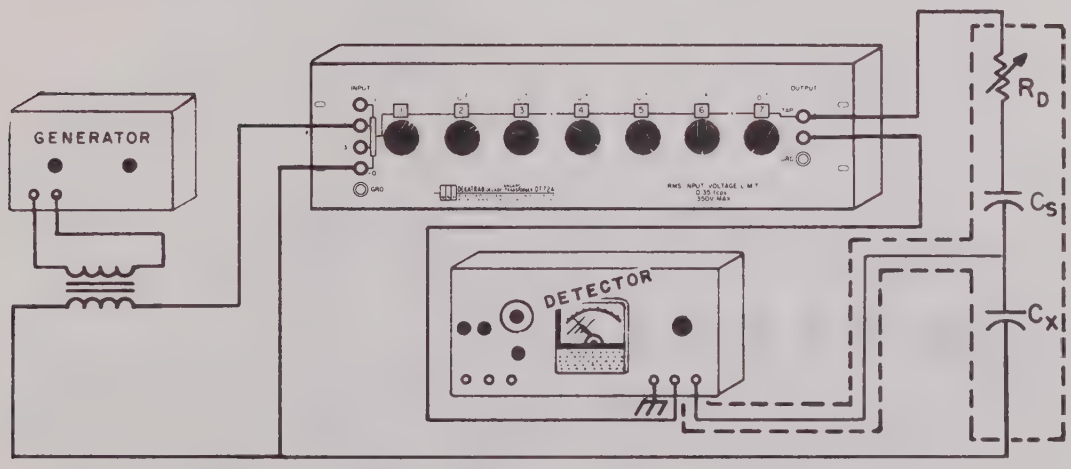


FIG. 2.5f

HIGH VALUE CAPACITORS

When high value capacitors are to be measured, the current can be supplied directly to the capacitance string and the transformer can be fed as shown in Figure 2.5g. This circuit permits a four-terminal measurement of the unknown capacitor to avoid lead and contact resistance and inductance errors. The transformer can be operated at a very low setting for obtaining a high ratio between the unknown and standard capacitors. However, transformer errors will increase for lower settings of the transformer dials.

$C_x = 10\ (S)\ C_s$ where S is the DT 72A dial setting

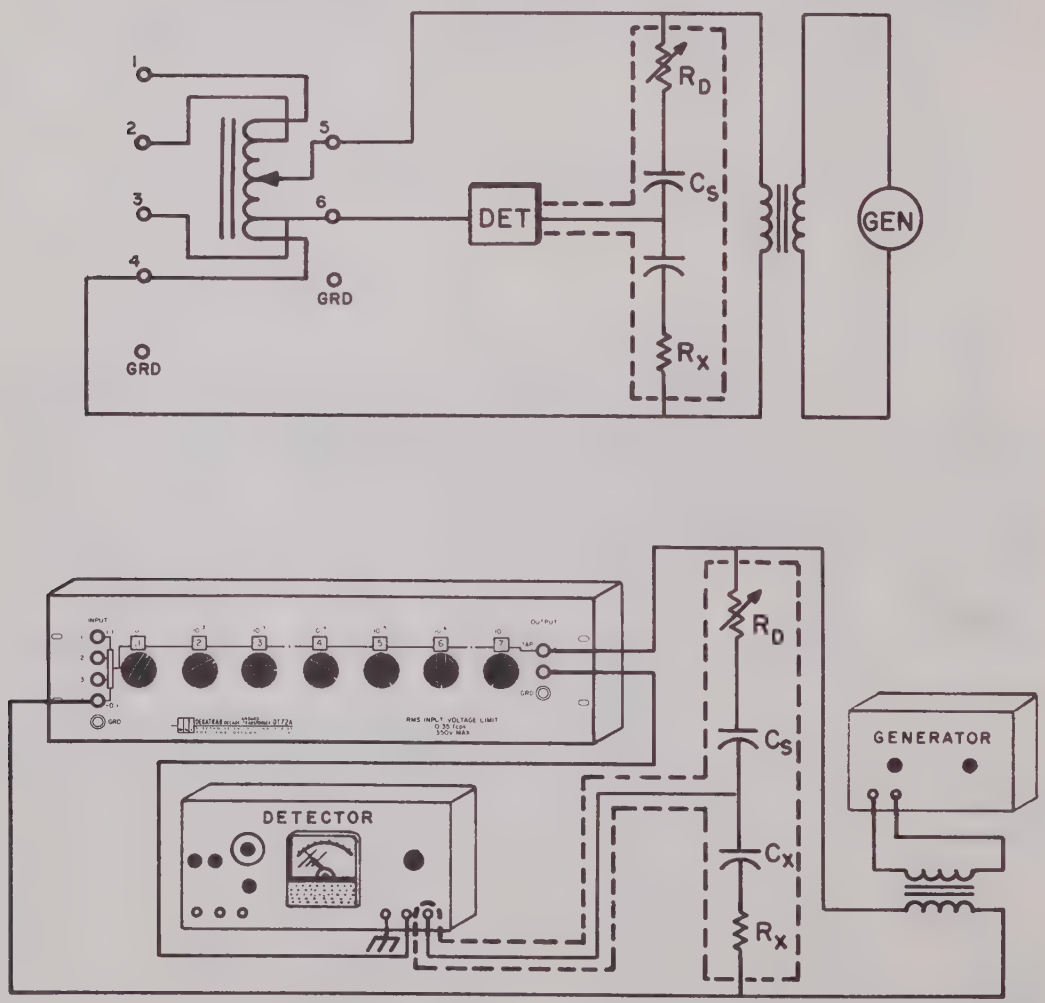


FIG. 2.5g

SECTION III

THEORY

Current flowing through a loop of wire creates a magnetic field. The change of flux inside a loop of wire creates a voltage. If a sine wave of voltage is applied to a zero resistance loop of wire, enough current will be drawn to create a flux which will change rapidly enough to generate a voltage in the loop equal to the applied voltage. If some of this flux goes through another loop of zero resistance wire nearby, a voltage somewhat less than the applied voltage will be generated. If a core of high permeability iron goes through the two loops of wire, most of the flux generated by the charging current will be confined to the iron core and will therefore go through both coils. As a result, the generated voltages in both coils will be exactly equal.

The accuracy of a transformer voltage divider is determined primarily by the permeability of the core material used in its construction. The accuracy can be improved by the use of proper winding techniques.

3.1 SOURCES OF ERROR

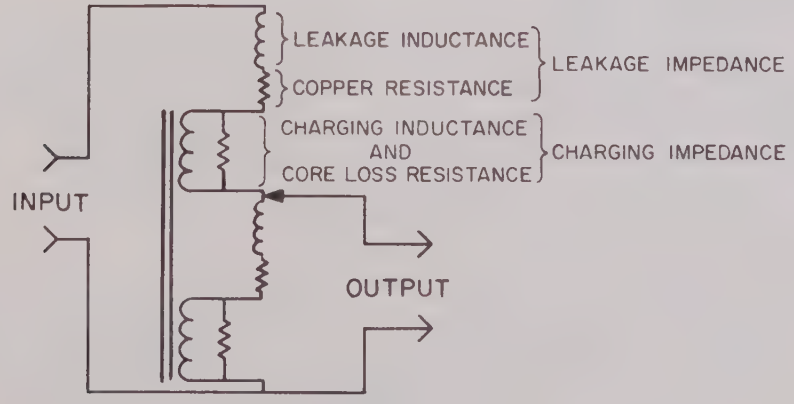


FIG. 3.1a

The equivalent circuit of a transformer shown in Figure 3.1a will have a leakage inductance which represents the flux which is generated by part of the winding but does not go through the other part of the winding, a series copper resistance, a primary inductance which results from the generation of the flux which threads through all of the windings, and a core loss resistance. The voltage which is generated by the charging inductance will be divided

exactly as the turns ratio, but the voltage across the leakage inductance and resistance will not be so perfectly divided because the leakage inductance and winding resistance will be different in different parts of the winding. The total voltage drop between taps is the sum of the transformer generated voltage and the voltage drop across the leakage inductance and resistance produced by the current flowing into the transformer. If the transformer secondary is open circuited, this current is determined by the charging inductance and core loss resistance. The voltages across the leakage and charging impedances will be directly proportional to these impedances, so the total voltage across the leakage impedance will be to the total input voltage as the leakage impedance is to the charging impedance.

LEAKAGE INDUCTANCE

Most of the flux in an air core transformer does not cut the other windings of the transformer so the leakage inductance of a transformer is approximately equal to the inductance of a winding of the same configuration on an air core. When this air core is replaced by iron the inductance will increase by a factor approximately equal to the permeance of the iron circuit relative to the permeance of the air that is replaced. This ratio is approximately equal to the permeability of the iron. Thus, if the iron has a permeability of one hundred thousand, we can expect the voltage across our leakage inductance to be about one one hundred thousandth of the input voltage. The current drawn by the core loss resistance will produce a quadrature voltage in the leakage inductance.

COPPER RESISTANCE

The transformer winding has resistance. The current through this winding resistance will produce additional voltage drops. The in-phase voltage will be about equal to the input voltage times the ratio of the copper resistance to the core loss resistance. The charging current will produce a quadrature voltage. Typical winding resistance is a few ohms.

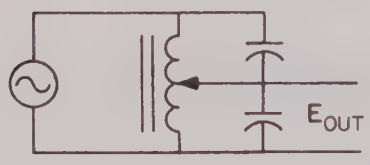
CORE LOSS RESISTANCE

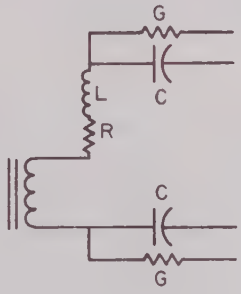
1000 turn windings on Supermaloy cores, which exhibit a premeability of 100,000, produce a core loss resistance of a few megohms at 1kc. This resistance reduces to a few hundred thousand ohms at 100 cps.

3.2 LOADING EFFECTS

CAPACITIVE LOADING

The tight winding required for optimum flux linkage produces a high inter-winding capacitance. This capacitance is so high that its impedance is quite comparable to, and is often greater than, the impedance of the charging inductance. Much of the current in the upper half of the winding flows in through the series leakage impedance and out through the leakage capacitance. In the lower half of the winding the reverse is true, the current flows in through the leakage capacitance and out through the leakage inducatance. Current through the leakage inductance produces a slight positive linearity deviation at high settings and a slight negative linearity deviation at low settings with a very low deviation at mid-scale, (see Figure 3.2a).





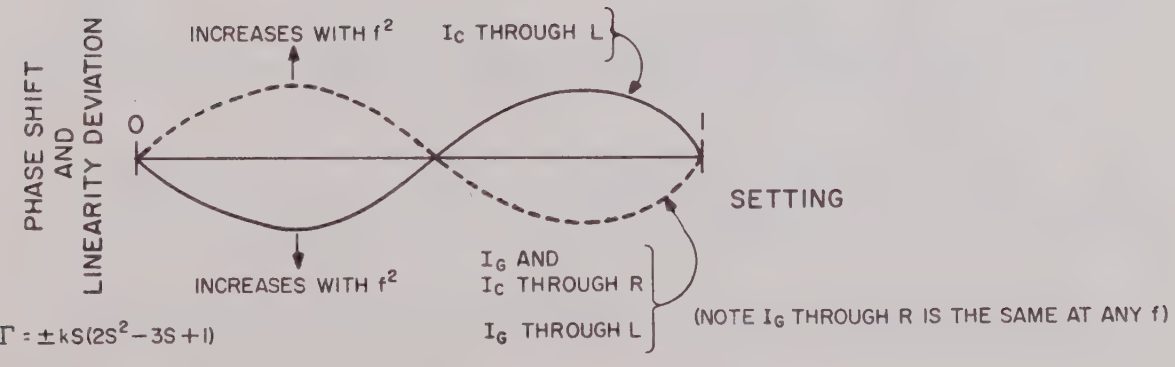


FIG. 3.2a

The capacitive current through the resistance of the windings produces a linearity deviation in the opposite direction so it is possible to build a transformer which will operate with these two effects almost balanced. Transformers of this design have been made with accuracies in the order of 0.02 ppm. The linearity deviation due to capacitive loading goes up with the square of the frequency. The phase shift due to capacitive loading goes up linearly with frequency.

The current passing through the leakage conductance of the insulation between windings causes a linearity deviation and phase shift when it passes through the leakage impedance. These changes are of the same polarity as those caused by the capacitive current through the leakage resistance. If the leakage conductance is fairly constant with frequency, the contribution of the leakage resistance will not change with frequency but the contribution of the leakage inductance will vary with frequency. Linearity deviation increases with the square of frequency and phase difference increases directly with frequency.

OUTPUT LOADING

A slightly different equivalent circuit can be considered for determining the effects of output loading on a transformer divider. The leakage impedance and copper resistance, which can be considered to be in series with the output lead of the transformer, can be measured at the output terminals by shorting the input terminals. The voltage drop produced by load current relative to the input voltage across this measured impedance will give the linearity deviation to be expected.

ACCURACY

The sum of all of these effects combined with other much smaller second order effects determine the accuracy at any setting, frequency, load and voltage combination.

SECTION IV

MAINTENANCE

4.1 PERIODIC MAINTENANCE

The following procedures should be performed periodically to insure maximum accuracy and reliability from the ESI MODEL DT 72A DECADE TRANSFORMER.

If the need for major repairs is apparent, it is recommended that the unit be sent to the factory for service and repair. Necessary repair information as well as any replacement parts will be furnished upon request. Unauthorized repairs will invalidate the instrument warranty. If the instrument is more than one year old when returned to the factory a reasonable charge may be expected for replacement of parts or complete reconditioning.

4.1.1 VISUAL INSPECTION

First inspect the instrument externally for dial orientation, damaged binding posts and binding post caps, and for dirt around the binding post insulators. Next remove the dust cover as described in Section 4.1.2 and inspect the unit for possible internal defects. These defects include such things as loose or broken connections and damaged or dirty switch contacts.

4.1.2 REMOVING THE DUST COVER

Prepare a soft, clean place on which the instrument may be set. Be sure that no projections or pointed objects will be underneath the panel. See that there are no metal filings in the area.

Remove the instrument from the rack and place it face down on the prepared surface.

Loosen the screws on the back of the instrument, and carefully slide the dust cover off.

4.1.3 CLEANING AND LUBRICATION

Clean the front panel with a soft, dry, lint free cloth being particularly careful to remove all dirt around the binding post insulators. The only internal components which require cleaning and lubricating are the switch decks.

The switch decks are carefully lubricated at the time of manufacture and are protected from contamination by the dust cover. They should rarely, if ever, need maintenance. It is recommended that they be cleaned or lubricated only if they are not making good electrical contact. If the switch decks need cleaning or lubrication, proceed as follows:

a) Apply solvent (Freon printed circuit solvent or equivalent) to the contact surfaces with a small brush or pipe cleaner.

b) Wipe surface with clean dry brush or dry with low pressure air.

c) Apply a thin coating of lubricant (Oak #2008 or equivalent) to the contact surface with a hypodermic needle.

d) Apply two drops of the same oil to each of the switch bearings and detent mechanisms.

e) Remove excess oil with a clean, dry cloth and remove all traces of lint with a soft brush.

4.1.4 REPLACING THE DUST COVER

Be sure that the interior of the dust cover is completely clear of all foreign material.

Slip the dust cover over the transformer and replace the screws.

SECTION IV

PARTS LIST

The following parts list is in alpha-numerical order of the circuit reference designator. Miscellaneous parts are included at the end of the list. Manufacturer of the part is given in a code number according to the Federal Supply Code for Manufacturers; see list of manufacturers below. Parts recommended as spares to sustain operation in isolated locations are indicated in the recommended spare parts column.

Parts manufactured by Electro Scientific Industries must be ordered from the factory. When making a factory order include the following information:

Model and serial number of the instrument
Electro Scientific Industries part number
Circuit reference designator
Description of part

CODE LIST OF MANUFACTURERS

01121	ALLEN-BRADLEY CO. Milwaukee, Wis.
11837	ELECTRO SICIENTIFIC INDUSTRIES Portland, Ore.

Ckt Ref	Description	Mfr	ESI Part No.	Qty Used	Recm SP
A_1	Xmfr Box Ass'y	11837	9535	1	
$R_{1,2}$	Resistor, 10k, 1/2w, ±10%	01121		2	
R_3	Resistor, 1k, 1/2w, ±10%	01121		1	
R_4	Resistor, 100Ω, 1/2w, ±10%	01121		1	
$R_{5,6,7}$	Resistor, 10Ω, 1/2w, ±10%	01121		3	
S_1	Switch, Rotary	11837	7217	1	
S_2	Switch, Rotary	11837	7213	1	

Ckt Ref	Description	Mfr	ESI Part No.	Qty Used	Recm SP
$S_{3,4,5,6,7}$	Switch, Rotary	11837	7214	5	
$T_{1,2}$	Transformer, Part of Ass'y A_1	11837		2	
T_3	Transformer, Part of Ass'y A_1	11837		1	
T_4	Transformer, Part of Ass'y A_1	11837		1	
	MISCELLANEOUS PARTS				
	Insulator, Binding Post	11837	8823	7	
	Window, Thick	11837	7243	4	
	Window, Thin	11837	7242	3	
	Binding Post	11837	1396	1	
	Binding Post	11837	1393	7	
	Binding Post Cap, Metal	11837	1172	2	2
	Binding Post Cap, Ins	11837	1170	6	4
	Knob, Bar	11837	1266	7	
	Dial, 3rd, 5th, and 7th	11837	7881	3	
	Dial, 1st	11837	7819	1	
	Dial, 2nd, 3rd and 6th	11837	7810	3	

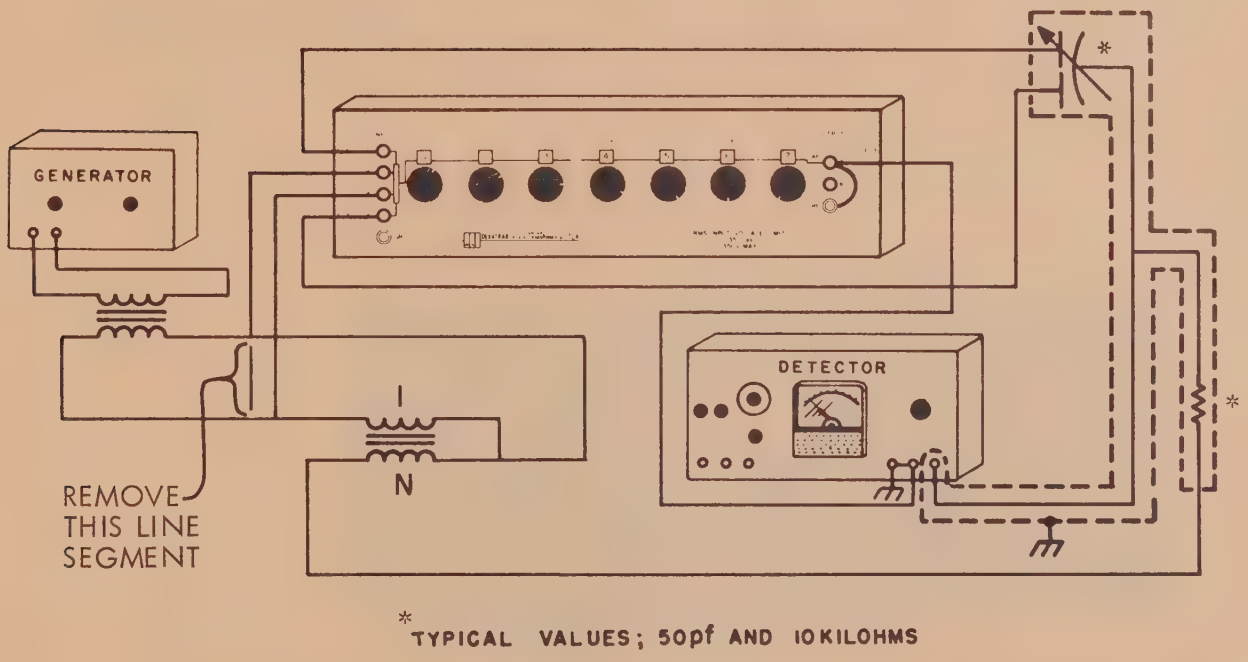
SEPTEMBER 1966

ESI® INSTRUCTION MANUAL CHANGES

Model DT 72A DEKATRAN

Instruction Manual dated April 1963

Page 2.4-1, Figure 2.4a: Correct lower diagram as follows:



* TYPICAL VALUES; 50pf AND 10KILOHMS

Part No. 7203-2

esi®
Electro Scientific Industries
7524 S. W. MACADAM AVE. • PORTLAND 19, OREGON

BRIDGES
AND
ACCESSORIES

NOVEMBER 1963

MODEL

RA 79

Instruction Manual

AC
RATIO ACCESSORY

SERIAL NUMBER_____

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LITHO IN U. S. A.

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TABLE OF CONTENTS

I INTRODUCTION

1.1 DESCRIPTION

1.2 APPLICATIONS

1.3 SPECIFICATIONS

1.4 AUXILIARY EQUIPMENT

II OPERATING INSTRUCTIONS

2.1 GENERATOR-DETECTOR CONNECTIONS

2.2 STANDARD DECADE TRANSFORMER CONNECTIONS

2.3 SYSTEM CORRECTIONS

2.3.1 PHASE CORRECTIONS

2.3.2 MAGNITUDE CORRECTIONS

2.4 VOLTAGE DIVIDER CALIBRATION

2.5 IMPEDANCE COMPARISONS

III THEORY

3.1 DIVIDER CALIBRATION

3.2 IMPEDANCE COMPARISON

3.3 CIRCUIT DESIGN

IV MAINTENANCE

4.1 VOLTMETER CALIBRATION

4.2 CIRCUIT DIAGRAM AND TEST VOLTAGES

V PARTS LIST

SECTION I

INTRODUCTION

1.1 DESCRIPTION

The ESI Model RA 79 RATIO ACCESSORY is both a quadrature generator and a voltmeter. The quadrature generator supplies an adjustable output voltage which is phase shifted 90° from the input voltage. The output voltage is proportional to the input voltage and its magnitude is adjusted by quadrature ratio controls. The quadrature generator input voltage is monitored by the voltmeter. Figure 1.1A illustrates a simplified block diagram of the RA 79.

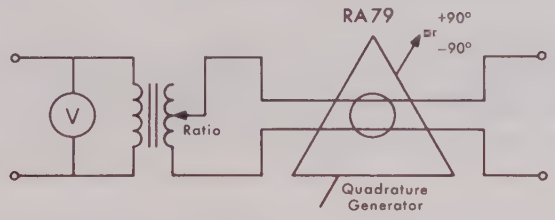
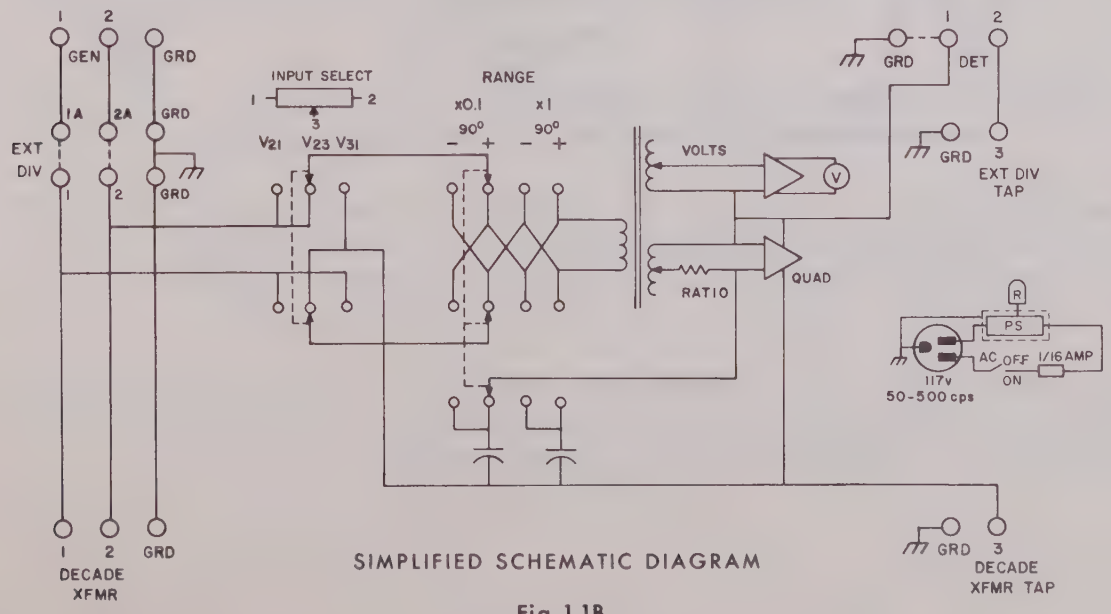


Fig 1.1A

The RA 79 is composed of three parts; (1) a precision decade transformer, (2) a solid state quadrature (integrating) amplifier, and (3) a solid state voltmeter. Panel controls are provided for magnitude control of the quadrature voltage, for voltmeter switching and ranging, and for +90° or -90° phase control of the quadrature voltage. Figure 1.1B illustrates the simplified schematic diagram of the RA 79.



SIMPLIFIED SCHEMATIC DIAGRAM

Fig 1.1B

1.2 APPLICATIONS

Generally the RA 79 is used as a part of a system for making ac ratio measurements. The quadrature output of the RA 79 is connected in series with the tap voltage of a standard decade transformer. Both the real and the imaginary components of a complex voltage ratio can then be determined from the dial settings of the decade transformer and the RA 79. Figure 1.2A illustrates a typical system in which the RA 79 is used to calibrate a voltage divider. In this circuit the generator voltage is applied to the uncalibrated divider and to a standard decade transformer which are connected in parallel. The output difference between the uncalibrated divider and the transformer is indicated by the detector. In-phase voltage differences are balanced by adjusting the decade transformer dials. The RA 79 RATIO dials are used to balance of the quadrature voltage differences.

The uncalibrated divider can be replaced by a standard and an unknown impedance connected in series. With the detector connected to the junction between the impedances the real and imaginary components of the ratio can be measured and used to find the value of the unknown impedance.

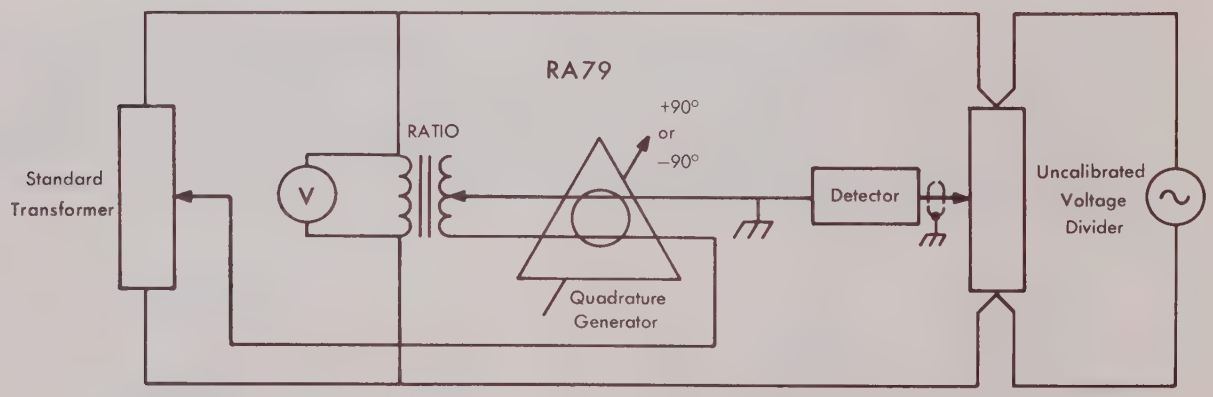


Fig 1.2A

1.3 SPECIFICATIONS

VOLTMETER

Voltage Range: 8 ranges selected with front panel switch. Full scale readings of 0.1, 0.3, 1, 3, 10, 30, 100, 300 volts and OFF.

Maximum Input Voltage: $(0.35 \times f_{cps})$ volts rms, 350 volts maximum. Voltmeter input terminals isolated from ground.

Frequency Range: 20cps to 200kc.

Accuracy: ±5% of full scale, 50cps to 20kc.
±10% of full scale, 20cps to 50cps and 20kc to 200kc.

Calibration: Reads rms value of a sine wave. Voltage indication proportional to average value of applied wave.

QUADRATURE GENERATOR

Recommended Frequency Range: 50 - 5000cps

Input Voltage: $(0.35 \times f_{cps})$ volts rms, 350 volts maximum. Input terminals isolated from ground.

Output Voltage: +90° or -90° to input voltage, 3.5 rms maximum output in series with a source impedance of less than two ohms.

Quadrature Ratio Accuracy: $\pm(2 + \Delta_f)\%$, where Δ_f = generator frequency accuracy.

Resolution: Ratio dial uses three decades plus a continuous resolution slidewire to provide 101,105 dial divisions.

Range: Two ratio range multipliers are provided: x0.1 (recommended for use between 50 and 500cps) and x1 (recommended between 500 and 5000cps). Full scale output is $\frac{0.01}{f_{kc}}$ x input voltage x range multiplier.

In-phase Deviation: The in-phase component of full scale quadrature voltage is less than ±10 ppm of full scale in-phase voltage, decreasing linearly to less than ±1 ppm at quadrature dial zero setting.

GENERAL

Power: 117/234v ±10% 50-500cps, 2 watts

Dimensions: 19" wide, 7" high, 9" deep

Weight: 14 lbs net, 20 lbs packed for shipping

1.4 AUXILIARY EQUIPMENT

For ratio measurements of the highest accuracy, equipment with the following specifications is recommended. All of these characteristics are adequately met by the ESI Models DT 72A Decade Transformer and 861A Generator-Detector.

DECADE TRANSFORMER

Resolution	0.1 ppm (0.00001%) of input
Range	-0.0111111 to +1.1111110
Maximum phase shift	(0.05 x f_{kc}) milliradians for settings above 0.1
Maximum input voltage	(0.35 x f_{cps}) volts rms; 350 volts maximum
Maximum tap current	1 ampere
Frequency range	50cps to 10kc
Input inductance	Approximately 100 to 400 henrys
Maximum output impedance	Approximately 5 ohms in series with 30 microhenrys

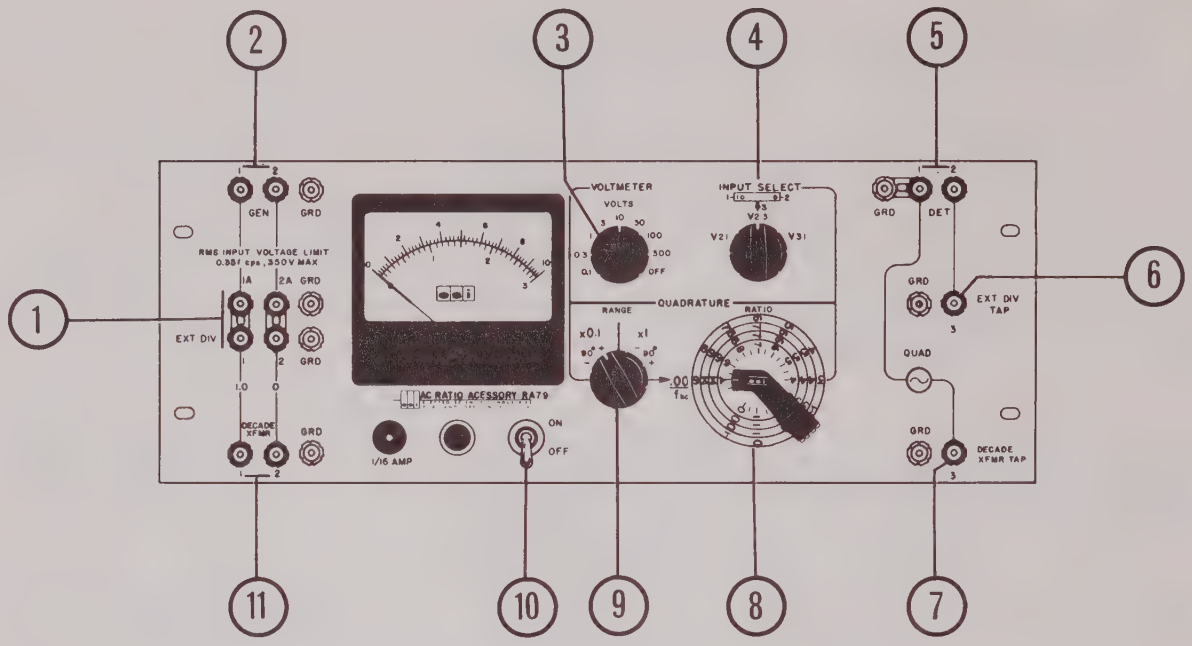
GENERATOR

Frequency	As required within the operating range of the transformer
Output voltage	Four ranges, 0-0.2v, 0-2v, 0-20v, and 0-200v with harmonic distortion less than 2%. Output impedance chosen to limit maximum power to one watt into a matched load.
Output circuit	Four output impedances, 0.4Ω, 1Ω, 100Ω, and 10kΩ. Guarded transformer with less than 50pf guard capacitance to ground, and less than 4pf from guarded terminal to ground.

DETECTOR

Frequency	Tuned to generator frequency.

Sensitivity	Full scale deflection with one microvolt or less input
Noise	Maximum short circuit input noise voltage to 1kc, 0.23 microvolts RMS
Input impedance	Approximately one megohm or more shunted by 80pf or less on the most sensitive range
Maximum input volts	200 volts RMS ac or 400 volts dc or peak
Indication	Linear mode sensitivity adjustable for full scale deflection with any input voltage between 1 microvolt and 100 volts
Selectivity	40db or more rejection of second harmonic and half frequency. Ultimate high and low frequency rejection in excess of 70db. Typical 3db bandwidth of 7% of nominal frequency.
Overload recovery	Typical 1kc overload recovery time of less than 0.1 seconds for 10^5 overload.



1. EXT DIV terminals - four terminals are provided for connecting to the external divider. Links may be connected as shown and a two terminal connection made to the external divider.

2. GEN terminals - two input terminals and a ground are provided for connecting an external generator.

3. VOLT control - selects the full-scale range of the voltmeter.

4. INPUT SELECT switch - selects input to voltmeter and quadrature generator.

5. DET terminals - two output terminals and a ground are provided for connecting to an external detector.

6. EXT DIV TAP terminal - the tap of the external divider is connected to this terminal.

7. DECADE XFMR TAP terminal - the tap of the external standard decade transformer is connected to this terminal.

8. RATIO dials - provides continuous adjustment of the magnitude of the quadrature voltage.

9. RANGE switch - selects the range and polarity of the quadrature voltage.

10. POWER switch - turns supply power ON and OFF.

11. DECADE XFMR terminals - two terminals are provided to connect to the input of the external standard decade transformer.

RA 79 PANEL LAYOUT

SECTION II

OPERATING INSTRUCTIONS

In most applications the RA 79 will be combined with a generator-detector and a standard decade transformer to produce a voltage ratio calibration system. The specifications for this auxiliary equipment are given in Section 1.3. The instructions for connecting (Sections 2.1 and 2.2) and calibrating (Section 2.3) the measurement system should be carefully followed before making Voltage Divider Calibrations (Section 2.4) or Impedance Comparisons (Section 2.5).

2.1 GENERATOR—DETECTOR CONNECTIONS

A rack-mounted generator-detector such as the ESI Model 861A GENERATOR-DETECTOR can be mounted above the RA 79 and connected by short, low loss links as shown in Figure 2.1A. The shield covers over these links (see Figure 2.2A) minimize the effects of stray electrical signals.

When using generator-detectors that are not mounted directly above the RA 79 it is important to shield the detector input. The shielding of the generator terminals is optional.

If the detector is internally grounded the link between the RA 79 DET 1 terminal and the GRD terminal should be removed, (the 861A detector is internally grounded).

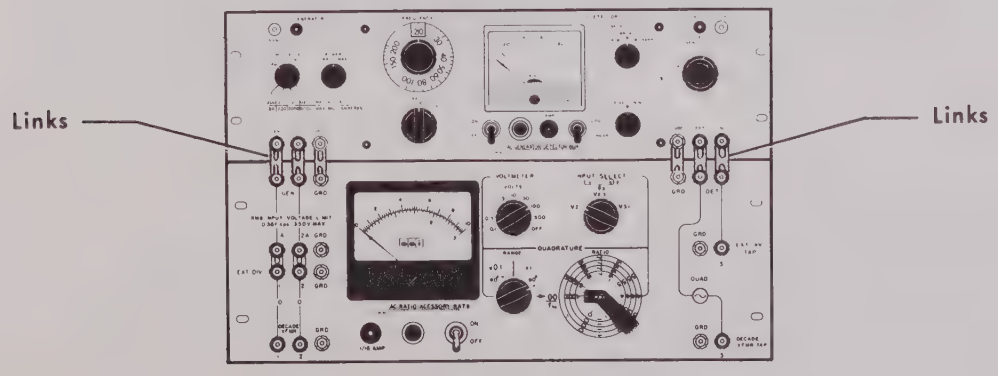


Fig 2.1A

2.2 STANDARD DECADE TRANSFORMER CONNECTIONS

Normally a standard decade transformer such as the ESI Model DT 72A will be rack-mounted below the RA 79. For most applications the decade transformer is connected as shown in Figure 2.2A. It is not necessary to shield the leads to the standard transformer. If the decade transformer is a DT 72A the DECADE XFMR 2 terminal on the RA 79 should be connected to the INPUT 3 terminal of the DT 72A. With other decade transformers make certain the DECADE XFMR 2 terminal on the RA 79 is connected to the "common" side of the decade transformer primary.

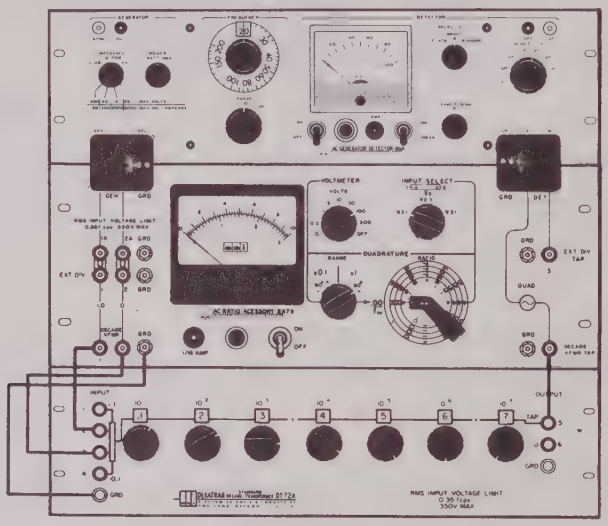


Fig 2.2A

2.3 SYSTEM CORRECTIONS

To make measurements of the highest accuracy with any system, it is necessary that the system be calibrated. Both phase and magnitude calibrations can be made for systems which use the RA 79.

Corrections can be used to increase measurement accuracy for a given set of conditions. However, the system must be recalibrated for each new set of parameters e.g. at a different generator frequency, for a different set of test leads, etc. If, for example, the system was calibrated at a generator frequency of 1000cps, then the correction terms obtained are good only at that frequency. If another frequency is to be used then the system must be recalibrated at that frequency.

2.3.1 PHASE CORRECTIONS

In the calibration procedure outlined in this section standard air capacitors with dissipation factors of 10^{-5} or better are used. Also, these capacitors have an inherent capacitance-to-ground in the range of 20 to 200pf (see dotted red lines in Figure 2.3A on next page).

Once the system has been calibrated and is being used to make a measurement, it is important that the component(s) being tested have a capacitance-to-ground on the same order of magnitude as that of the air capacitors (that is, in the range of 2 to 2000pf). If the capacitance to ground of the component(s) is not in this range then the system must be recalibrated. If recalibration is necessary, the capacitance to ground of the standard air capacitors is intentionally "spoiled" by adding enough capacitance to ground to approximate that of the component, and a new curve is drawn.

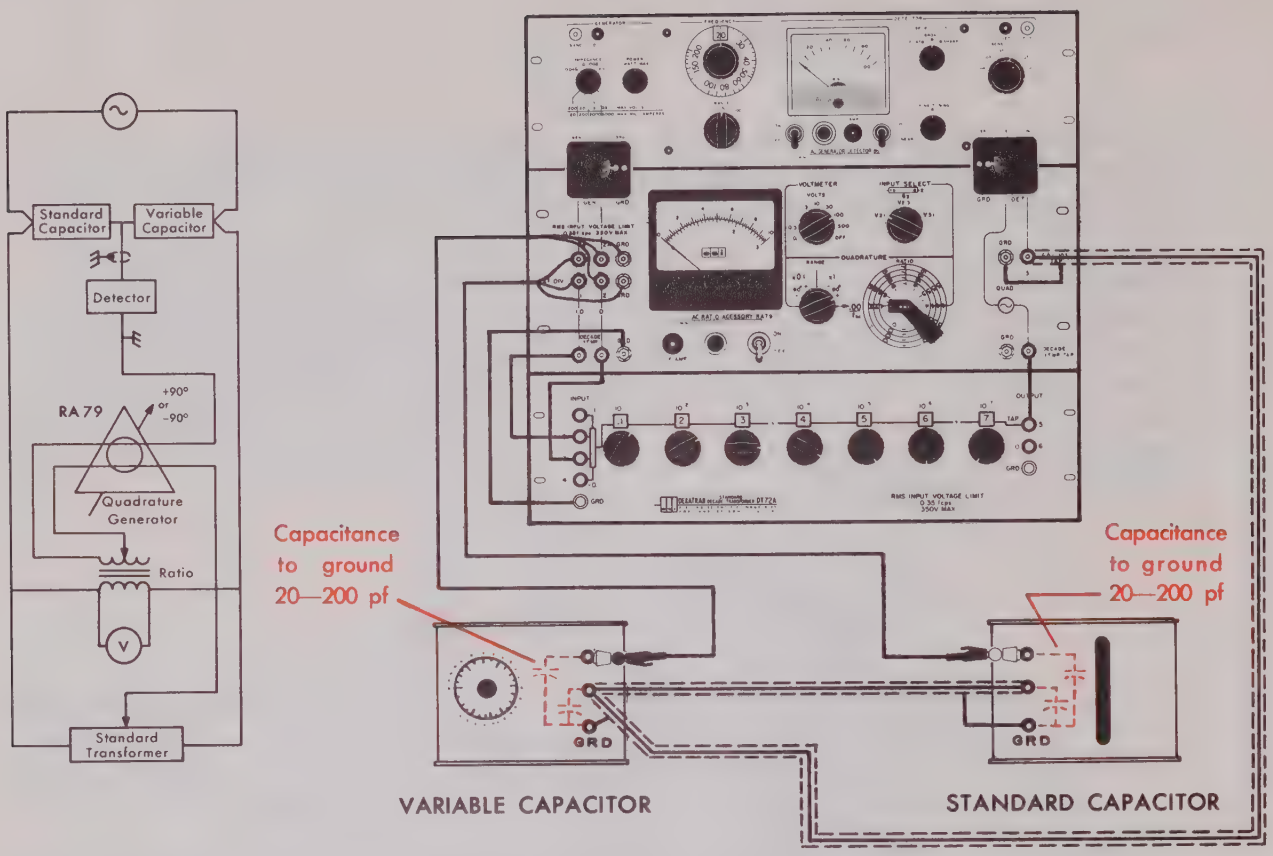


Fig 2.3A

The graph in Figure 2.3B illustrates a sample correction curve for the ac ratio measurement system. The phase correction is plotted for each of the first decade dial settings (with all other dials set at zero). For a standard decade transformer dial setting of .450, 000, 0 the RATIO dial error would be read as -.0000040. If the RATIO dials had actually read .000, 670 when the standard transformer dials read .450, 000, 0 then the corrected RATIO dial reading should be .000, 670 + (-.0000040) = .000, 666, 0.

EQUIPMENT REQUIRED:

A standard 1000pf air capacitor with a dissipation factor better than 10^{-5} and a capacitance-to-ground from either terminal less than 200pf.

A variable 1000pf air capacitor with a dissipation factor better than 10^{-5} and capacitance-to-ground from either terminal less than 200pf.

Set the KELVIN KLIPS®, four terminal klips (ESI Part #KK110).

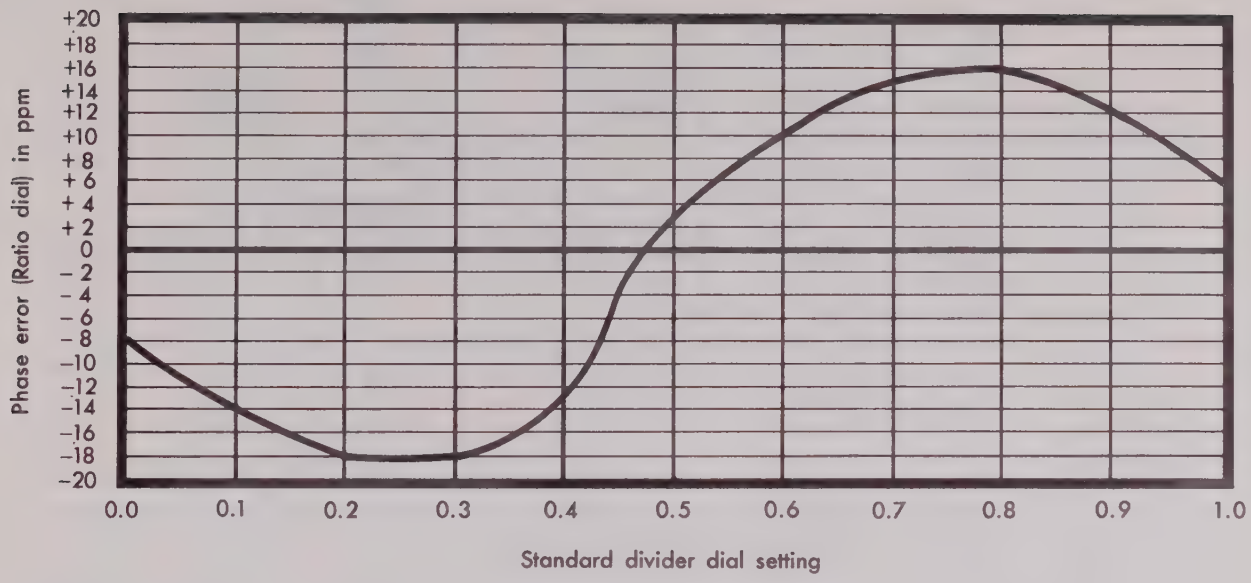


Fig 2.3B

CALIBRATION PROCEDURE

1) Connect the system as shown in Figure 2.3A.

2) Set the standard decade transformer dials to .500, 000, 0 and the variable capacitor to 1000pf.

3) Set the RA 79 INPUT SELECT switch to the V21 position.

4) Set the RA 79 VOLTS switch to the 100 volt range.

5) Turn the RA 79 ON.

6) Turn the generator-detector ON and allow five minutes for warm-up.

7) Set the RA 79 RANGE switch to the + position on the x1 range.

8) Set the generator frequency to 1000cps and the output voltage to 100 volts, (read the output voltage on the RA 79 meter).

9) Set the sensitivity of the detector so the null meter reads on scale, (increase sensitivity as required).

10) Alternately adjust the RA 79 RATIO dials and the variable capacitor for a null balance on the detector (the RATIO dials must be readjusted each time the variable capacitor is changed). The standard decade transformer dials may be used to attain a final balance if the variable capacitor does not have sufficient resolution. The only qualification is that the setting of the standard decade transformer must not be altered by more than 100 ppm. NOTE: If the RATIO dial setting appears to be less than zero (.000, 000, 0) then switch the outermost dial to the -1 position and balance with the inner dials. The inner dials are read as plus. For example, a dial setting of -19990 should be read as -00010.

11) When a null balance has been reached at the desired degree of detector sensitivity, plot the dial setting of the RATIO dials on a graph similar to the one shown in Figure 2.3B.

12) Repeat steps 10 and 11 for standard decade transformer dial settings of (.600, 000, 0), (.700, 000, 0), (.800, 000, 0), and (.900, 000, 0). The variable capacitor setting at null balance will decrease with each new divider dial setting.

13) Reduce the generator voltage to avoid shock hazzard and reconnect the system as shown in Figure 2.3C. (The KELVIN KLIPS® are interchanged.)

14) Reset the generator voltage to 100v and repeat steps 10 and 11 for standard decade transformer dial settings of (.400, 000, 0), (.300, 000, 0), (.200, 000, 0), and (.100, 000, 0). The variable capacitor setting at null balance will decrease with each new transformer dial setting.

15) Reduce the generator voltage and reconnect the system as shown in Figure 2.3D.

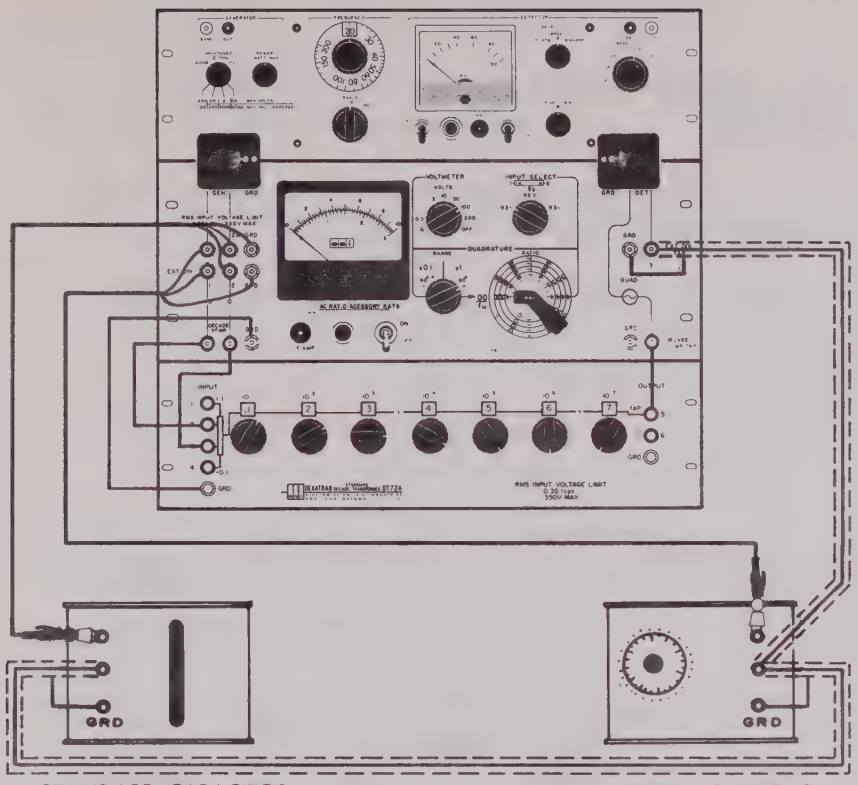
16) Set the standard decade transformer dials to .000, 000, 0.

17) Set the variable capacitor to 1000pf.

18) Reset the generator voltage to 100v.

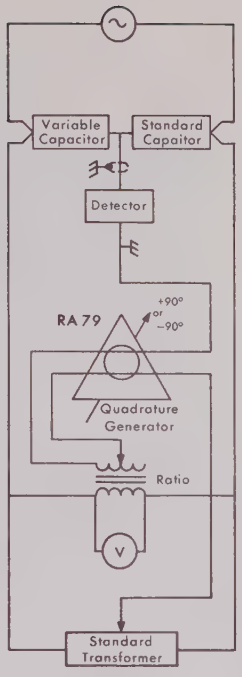
19) Alternately adjust the RA 79 RATIO dials and the standard decade transformer dials for a null balance on the detector.

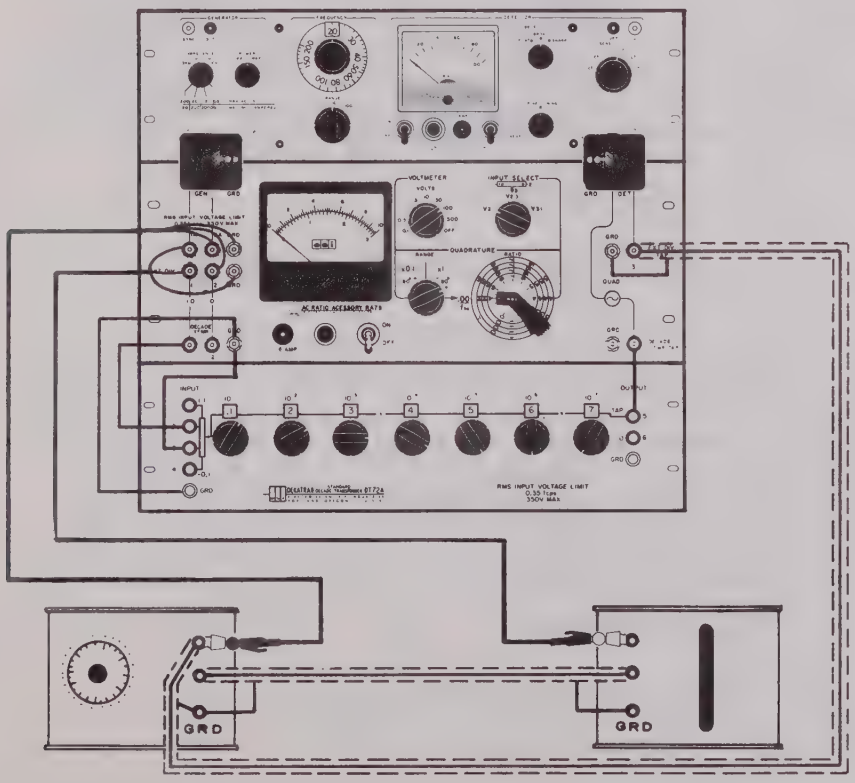
20) When a null balance has been reached at the desired degree of detector sensitivity, plot the dial setting of the RATIO dials.



STANDARD CAPACITOR VARIABLE CAPACITOR

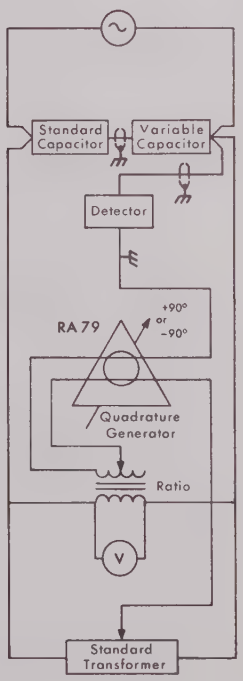
Fig 2.3C





VARIABLE CAPACITOR STANDARD CAPACITOR

Fig 2.3D



21) Record the setting of the standard decade transformer dials for use in Section 2.3.2 (Magnitude Calibration).

22) Reduce the generator voltage and reconnect the system as shown in Figure 2.3E.

23) Set the standard decade transformer dials to 1.000, 000, 0.

24) Repeat steps 18, 19, and 20.

25) Record the setting of the standard decade transformer dials for use in Section 2.3.2 (Magnitude Calibration).

26) Draw the graph (Figure 2.3B) from the points plotted. This graph is now used for making phase corrections (corrections for the RATIO dials) for all measurements.

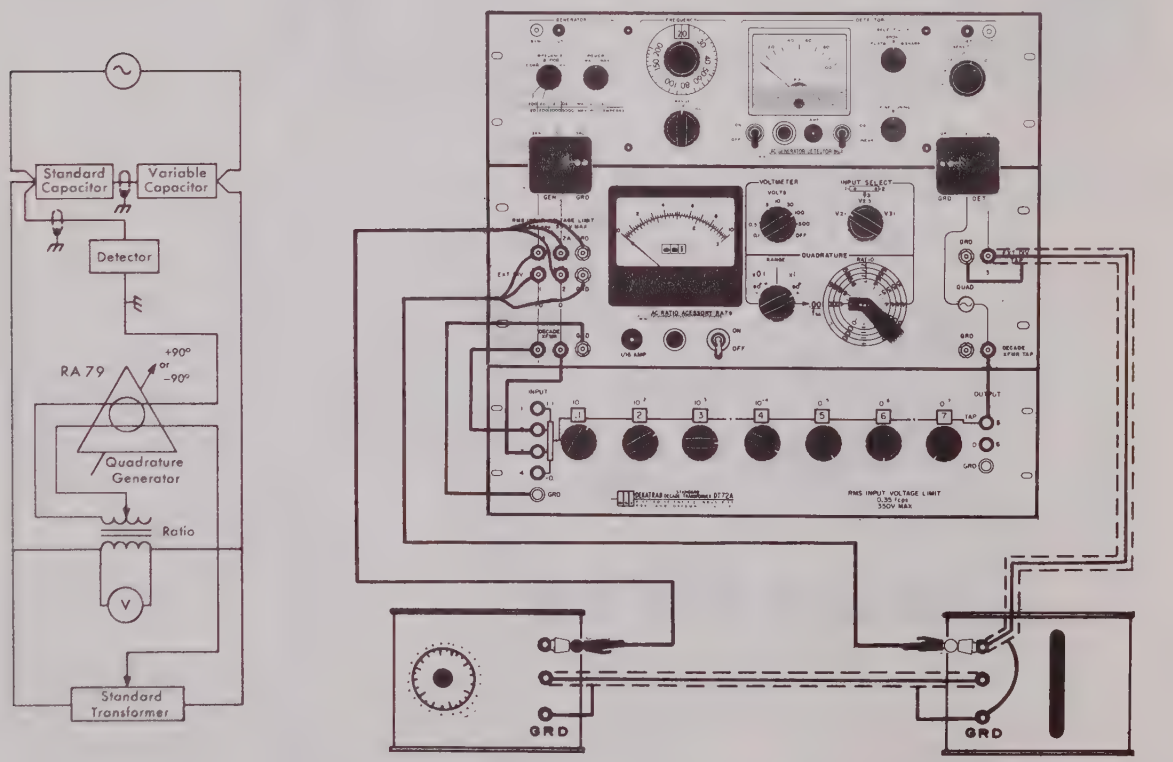


Fig 2.3E

2.3.2 MAGNITUDE CORRECTIONS

Magnitude corrections, necessitated by voltage drop in the leads, are determined by plotting the zero and full scale corrections (end corrections) on a graph and linearly interpolating the error for any dial setting in between. If the zero-end correction was +0.7 ppm and the full scale (1.000, 000, 0) correction was -0.4 ppm, the graph would be as shown in Figure 2.3F. The correction for a standard decade transformer dial setting of .100, 000, 0 for this example would be +0.6 ppm. The actual setting of the standard decade transformer is then .100, 000, 6.

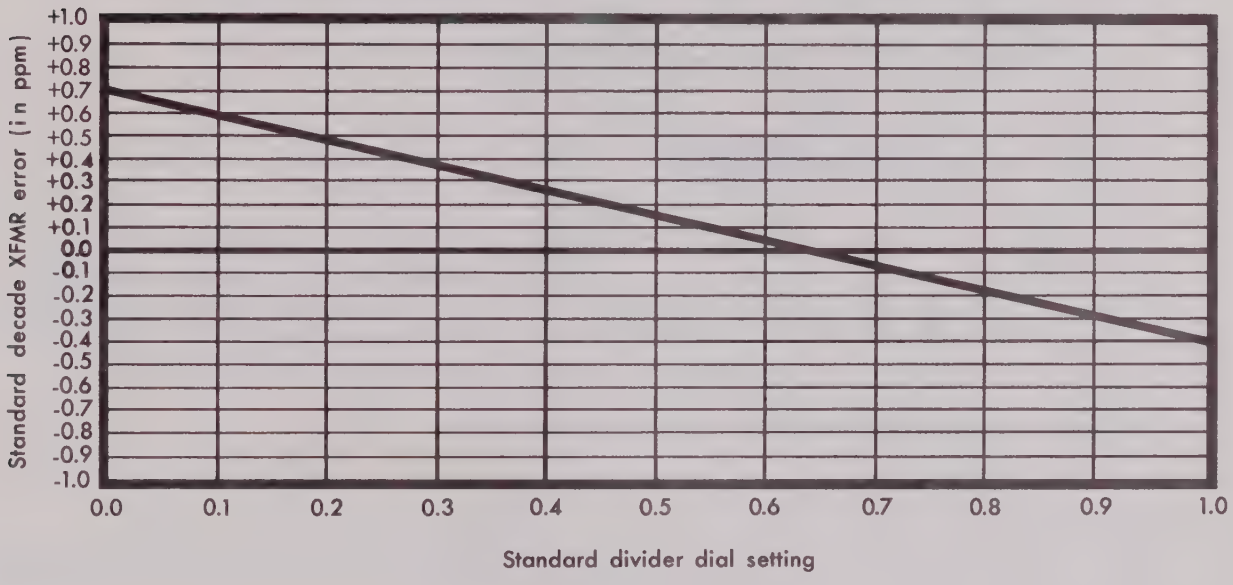


Fig 2.3F

In steps 21 and 25 of the preceding section the values recorded were the zero and full scale magnitude correction, respectively. Using this data, the magnitude correction graph for voltage drop in the leads can be drawn. The value recorded in step 21 is plotted at the zero (left) end of a graph similar to the one in Figure 2.3F. The value recorded in step 25 is then plotted on the full-scale (right) end. These two points are connected by a straight line. The system correction for any standard decade transformer dial setting can then be interpolated from this graph.

Normally, the standard decade transformer will be accompanied by a calibration certificate. The corrections indicated on this

certificate should be added to the corrections determined from the graph. If these combined values are plotted, an "s" curve similar in shape to the one in Figure 2.3B results.

The corrections on the standard decade transformer certificate are normally determined with no load on the transformer. This means that these values are not absolutely correct if the circuit in which the transformer is being used is loading it. If magnitude accuracy to a tenth of a ppm is desired with the ratio measurement system, it is necessary to be concerned with the additional errors due to loading. To determine the absolute correction factors replace the standard and variable air capacitors with a calibrated transformer divider. Comparisons are then made between the two dividers at each setting of the first decades and the error is plotted in a similar manner to that explained in Section 2.3.1.

2.4 VOLTAGE DIVIDER CALIBRATION

The ac voltage ratio measuring system can be used to calibrate either resistive or transformer type voltage dividers. Before the divider being calibrated is connected, the system should be calibrated as outlined in Section 2.3. When the system has been calibrated connect the uncalibrated divider as shown in Figure 2.4A.

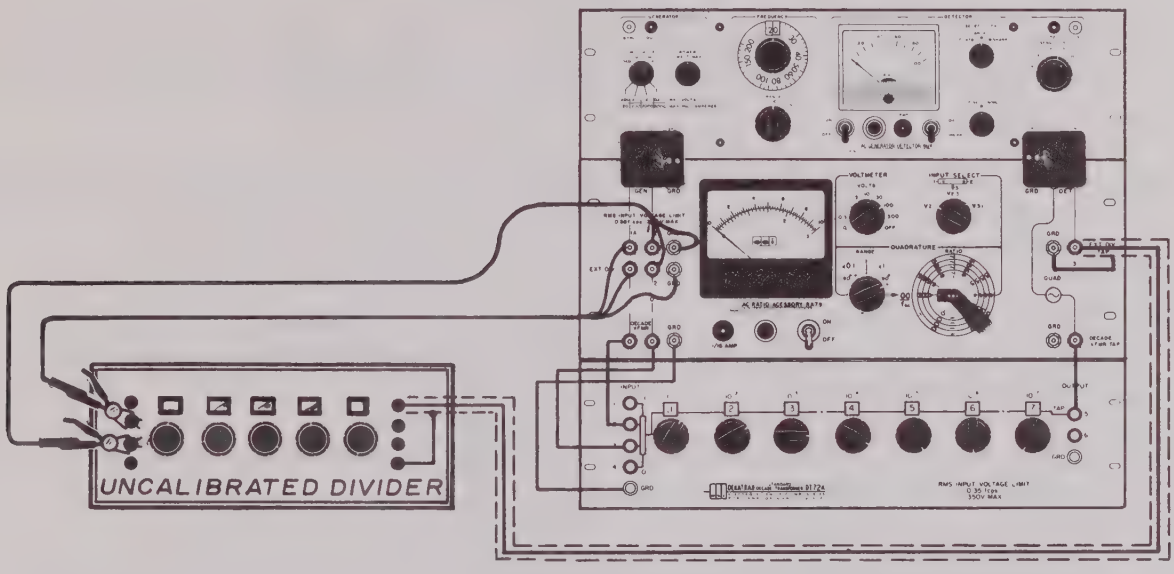


Fig 2.4A

In this section the following symbols are used:

s = dial setting of the standard divider
s'= dial setting of the uncalibrated divider
q = dial setting of the quadrature RATIO dial
α = phase angle between the generated voltage and the common-to-tap voltage of the divider being calibrated

CALIBRATION PROCEDURE

1) Turn the RA 79 ON.

2) Set the RA 79 INPUT SELECT knob to the V21 position.

3) Set the RA 79 VOLTS switch to the desired voltmeter range (adjust according to generator voltage to be used).

Turn the generator-detector ON and adjust the voltage as desired. Allow at least a five minute warm-up period.

CAUTION: Do not exceed the maximum voltage limitations of any of the system elements. The ESI Model 861A Generator-Detector is designed to protect the equipment from excessive power. Note, however that voltages exceeding maximum transformer input voltage may produce distortion and lead to erroneous measurements.

4) Set the generator frequency to 1000cps. If other frequencies are used the system must be recalibrated according to Section 2.3 at the desired frequency.

5) Set the RA 79 RANGE switch to either + on the x0.1 range if the generator frequency is less than 500cps or to + on the x1 range if the generator frequency is 500cps or more.

6) Set the uncalibrated divider to the reading to be checked. (Normally each setting of the decades being calibrated are checked with all other decades set to zero.)

7) Set the sensitivity of the detector so the null meter reads on scale, (increase the sensitivity as required).

8) Alternately adjust the RA 79 RATIO dials and the standard decade transformer dials for a null balance on the detector (the RATIO dials must be readjusted each time the standard decade transformer dials are changed). If the RATIO dial setting appears to be less than zero (.000, 000, 0) then switch the outermost dial to the -1 position and balance with the inner dials. The inner dials are read as +.

9) Increase the detector sensitivity and readjust the q and s dials until the desired degree of sensitivity has been attained.

10) Note the q and s dial readings and apply the system corrections found in Section 2.3. Use these corrected values in steps 11 and 12.

11) The calibrated correction for the divider being calibrated ($\Delta s'$) is given by the equation:

$$\Delta s' = (s^2 + q^2)^{\frac{1}{2}} - s'$$

12) The phase angle difference (α) between the generated voltage and the tap voltage of the divider being calibrated is given by the formula

$$\alpha = \tan^{-1} \frac{q}{s}$$

2.5 IMPEDANCE COMPARISONS

In this section the following symbols are used:

s = dial setting of the standard divider

q = dial setting of the quadrature RATIO dials

D_1 = dissipation factor of standard

D_2 = dissipation factor of unknown

Z_1 = impedance of standard

Z_2 = impedance of unknown

The ac ratio measuring system can be used to determine the voltage or impedance ratio of any two similar impedances, e.g. two capacitors, two inductors, or two resistors. The impedances are connected to the system as illustrated in Figure 2.5A.

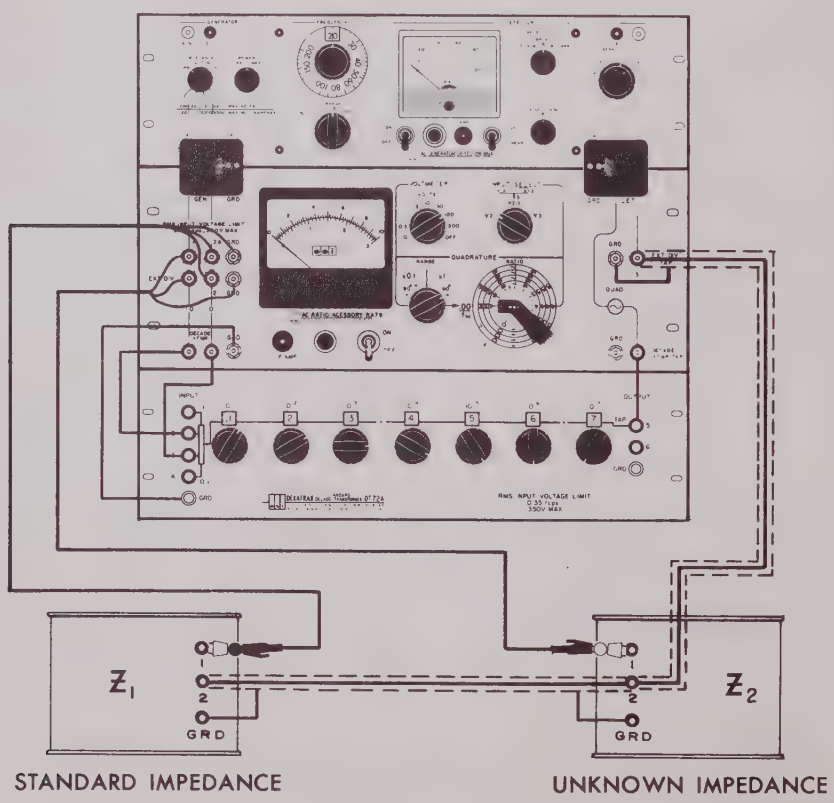


Fig 2.5A

The impedance ratio ($\frac{Z_1}{Z_2}$) is found using the relationship

$$\frac{Z_1}{Z_2} = \left[\frac{s^2+q^2}{(1-s)^2+q^2}\right]^{\frac{1}{2}} \qquad \text{OR} \qquad Z_2 = Z_1\left[\frac{(1-s)^2+q^2}{s^2+q^2}\right]^{\frac{1}{2}}$$

However, quite often it is not the ratio of the impedances that is desired. Instead the ratio of the reactances (X_1, X_2), or even more specifically the ratios of the capacitances (C_1, C_2), inductances (L_1, L_2), or resistances (R_1, R_2) in the equivalent series circuit are desired. The equations for these quantities are given below:

1) $$R_2 = R_1\left[\frac{\frac{q}{D_1} - q^2 + s(1+s)}{s^2+q^2}\right] \cong \left[\frac{\frac{q}{D_1} + s(1-s)}{s^2}\right] \text{ for } q \ll s$$

2) $$C_2 = C_1\left[\frac{s+qD_2}{(1-s)-qD_1}\right]$$

3) $$L_2 = L_1\left[\frac{(1-s)-qD_1}{s+qD_2}\right]$$

where the subscript 1 indicates the standard, and 2 indicates the unknown

By making assumptions about D_1 the above equations may be simplified. In most cases the D of a standard resistor will approach infinity. The first equation will then be

4) $$R_2 \cong R_1\left[\frac{1-s}{s}\right] \text{ for } q \ll s, \; D \to \infty$$

With most standard capacitors the D will be nearly zero. The second equation will then be

5) $$C_2 \cong C_1\left[\frac{s}{1-s} + \frac{q^2}{s(1-s)^2-q^2}\right] \; D \to 0$$

For high Q inductors the third equation will reduce to

$$6) \qquad L_2 \cong L_1 \left[\frac{s}{s^2+q^2} - 1 \right]$$

PROCEDURE

1) Connect the standard and unknown as shown in Figure 2.5A.

2) Turn the RA 79 ON.

3) Set the RA 79 INPUT SELECT knob to the V21 position.

4) Set the RA 79 VOLTS switch to the desired voltmeter range (adjust according to generator voltage to be used).

   Turn the generator-detector ON and adjust the voltage as desired. Allow at least a five minute warm-up period.

CAUTION: Do not exceed the maximum voltage limitations of any of the system elements. The ESI Model 861A Generator-Detector is designed to protect the equipment from excessive power. Note, however, that high voltages may produce distortion and lead to erroneous measurements.

5) Set the generator frequency to 1000cps. If other frequencies are used the system must be recalibrated according to Section 2.3 at the desired frequency.

6) Set the RA 79 RANGE switch to either + on the x0.1 range if the generator frequency is less than 500cps or to + on the x1 range if the generator frequency is 500cps or more.

7) Set the sensitivity of the detector so the null meter reads on scale (increase the sensitivity as required).

8) Alternately adjust the RA 79 RATIO dials and the standard decade transformer dials for a null balance on the detector (the RATIO dials must be readjusted each time the standard decade transformer dials are changed). If the RATIO dial setting appears to be less than zero (.000, 000, 0) then switch the outermost dial to the -1 position and balance with the inner dials. The inner dials are read as +.

9) Increase the detector sensitivity and readjust the q and s dials until the desired degree of sensitivity as been attained.

10) The equations for calculating the unknown resistance, capacitance and inductance are given in equations 4, 5, and 6.

11) The phase angle difference ($\angle Z_1 - \angle Z_2$) between the voltage across the unknown and the generator voltage is given by the formula;

$$\angle Z_1 - \angle Z_2 = \alpha + \beta$$

Where:

$$\alpha = \tan^{-1} \frac{q}{s}$$

$$\beta = \tan^{-1} \frac{q}{(1-s)}$$

SECTION III

THEORY

3.1 DIVIDER CALIBRATION

The block diagram in Figure 3.1A illustrates a typical circuit employing the RA 79. In this illustration the system is being used to calibrate a divider, however, the theory presented in this section is useful for many applications.

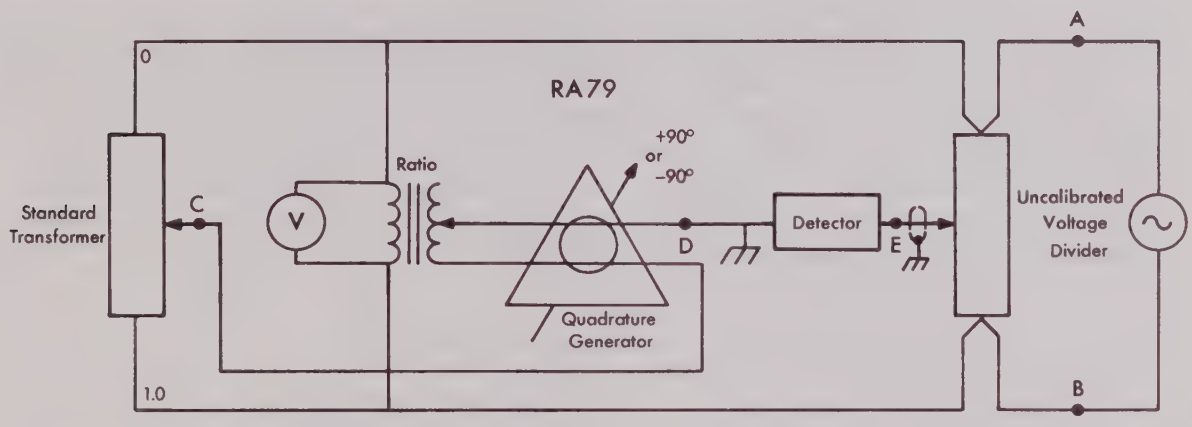


Fig 3.1A

Vector diagrams are used to explain the function of the RA 79 quadrature generator in the circuit above. In the circuit diagram (above) and in the vector diagrams (Figures 3.1B and 3.1C) the following symbols are used:

s = dial setting of the standard divider

s'= dial setting of the uncalibrated divider

q = dial setting of the quadrature RATIO dials

The identification points A, B, C, D, and E in Figures 3.1A, 3.1B, and 3.1C indicate the potentials at the corresponding points in Figure 3.1A.

These points correspond to the following RA 79 terminals:

A - GEN 1, EXT DIV 1A

B - GEN 2, EXT DIV 2A

C - DET 2, EXT DIV TAP 3

D - DET 1

E - DECADE XFMR TAP 3

To simplify the notations, unity voltage is assumed thus eliminating the necessity of multiplying the dial setting by the generator voltage.

If we assume negligible phase shift of the voltage at the tap of the standard decade transformer then the phase angle between the two tap voltage vectors s and 1-s (AC and CB) is zero. This means that the line AB in Figure 3.1B is a straight line. The vector representing the voltage drop across the s' (AE) portion of the uncalibrated divider will normally have a phase angle (α) other than zero. This means that this voltage is out of phase with the generated voltage (AB). Observe that since points D and E do not coincide these points are not at the same potential.

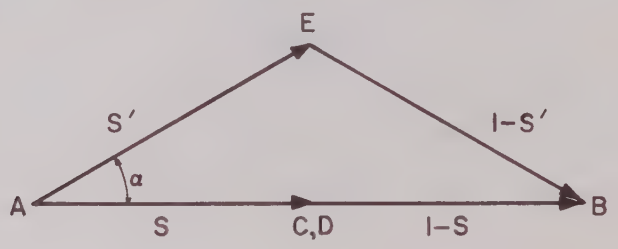


Fig 3.1B

Since it is necessary that the feed points of the detector (which are D and E) be at the same potential for a null balance, an auxiliary voltage q (CD) is introduced. This is accomplished with the RA 79 quadrature generator (see Figure 3.1A and 3.1C).

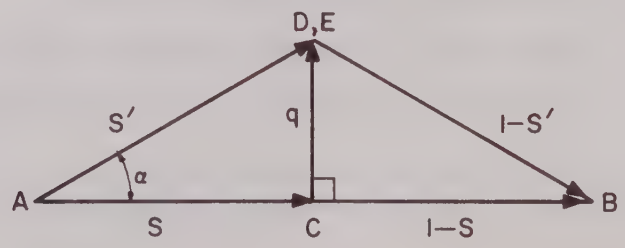


Fig 3.1C

The quadrature voltage q (CD) is injected 90° out of phase (at right angles on the vector diagram) to the generator voltage (AB). It is inserted between the

tap of the standard and the grounded side of the detector (between points C and D). Its magnitude is adjusted until it just equals the voltage differential between C and E. This produces a null balance in the detector and provides known quantities, s (standard decade transformer dial setting) and q (RA 79 RATIO dial setting) from which the unknowns α and s' can be calculated.

3.2 IMPEDANCE COMPARISONS

Normally, the component parts of the equivalent series circuit of an impedance, R and X (where R is the resistance and X is the reactance), are quantities for which data is desired. Figures 3.2A and 3.2B illustrate the relationships of the components R_1 and X_1, and R_2 and X_2 to the impedances Z_1 and Z_2.

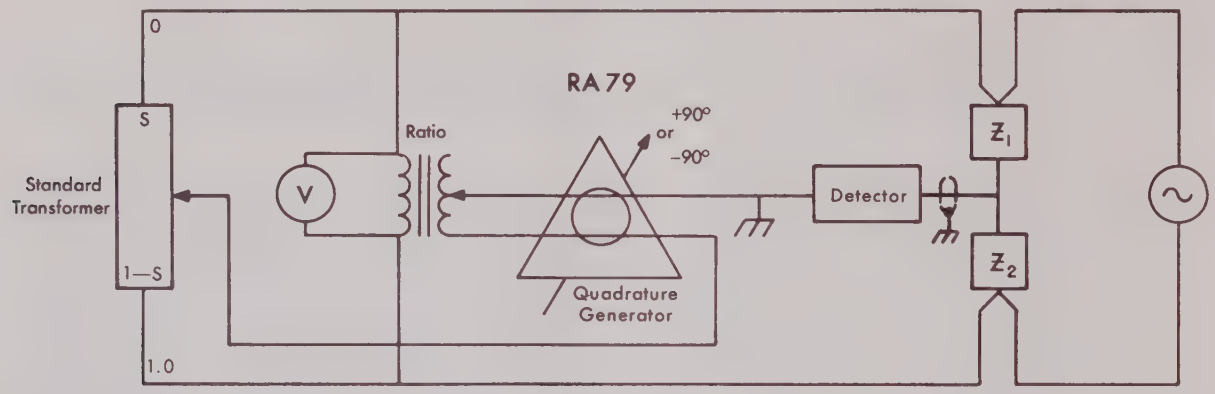


Fig 3.2A

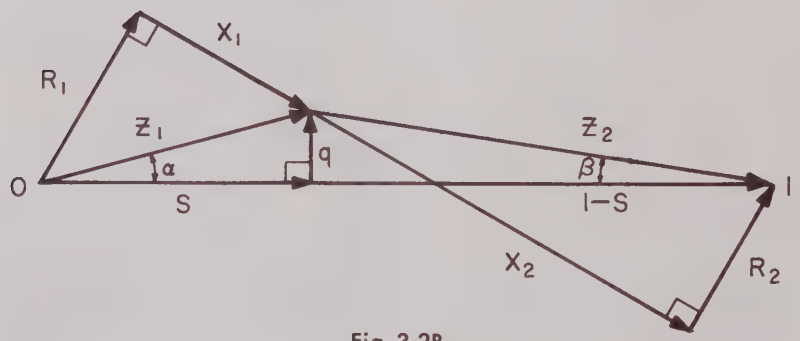


Fig 3.2B

In these illustrations Z_1 is the standard or known impedance and Z_2 is the unknown impedance.

Referring to Figure 3.2B it can be seen that

$$1) \qquad \frac{Z_1}{Z_2} = \frac{s+jq}{(1-s)-jq} = \frac{X_1(j+D_1)}{X_2(j+D_2)}$$

Where: $D_1 = \frac{R_1}{X_1}$ = Dissipation factor of Z_1

$D_2 = \frac{R_2}{X_2}$ = Dissipation factor of Z_2

By cross multiplying and separating the real and imaginary parts we get

$$2) \qquad X_2(D_2 s - q) + j(X_2)(s + D_2 q) = X_1(q + D_1 - D_1 s) + j(X_1)(1 - s - D_1 q)$$

From the real and the imaginary parts of equation 2, two equations can be written

$$3) \qquad X_1(D_1 - s D_1 + q) = X_2(s D_2 - q)$$

and

$$4) \qquad X_1(1 - s - D_1 q) = X_2(s + D_2 q)$$

By separating like quantities in equations 3 and 4, two equations for the unknown X_2, are formed

$$5) \qquad \frac{X_1}{X_2} = \frac{s D_2 - q}{(1-s)D_1 + q}$$

or

$$6) \qquad \frac{X_1}{X_2} = \frac{s + q D_2}{(1-s) - q D_1}$$

Also, by solving equations 5 and 6 simultaneously, it is possible to determine D_2 in terms of D_1, s and q

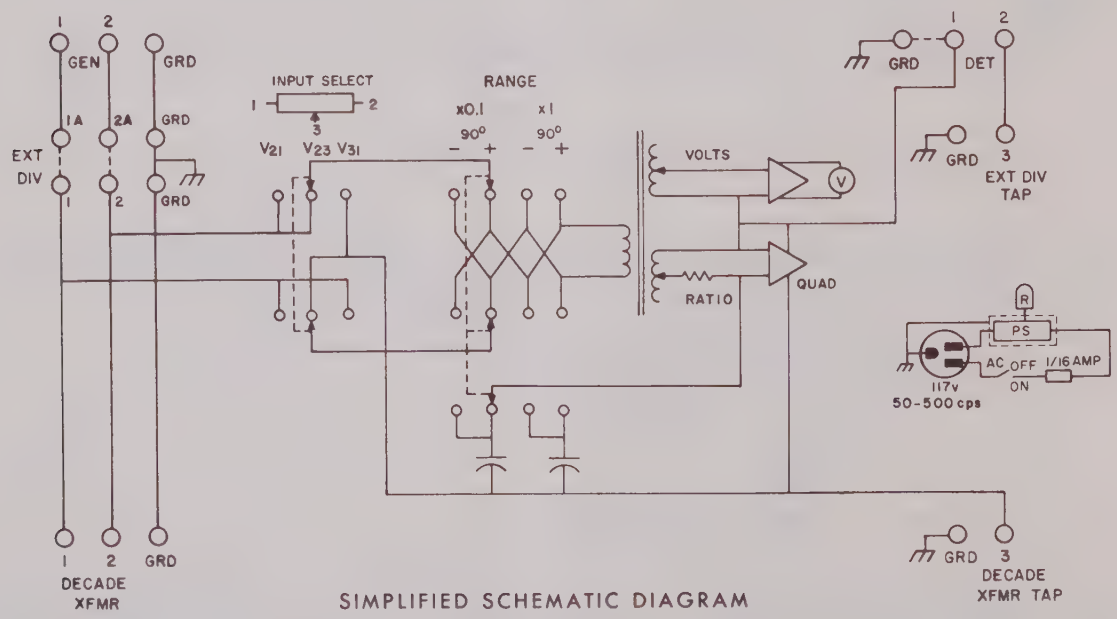
$$7) \qquad D_2 = \frac{s D_1 (1-s) + q - q^2 D_1}{s(1-s) - q D_1 - q^2} \cong \frac{s D_1 (1-s) + q}{s(1-s) - q D_1}$$

Equations 6 and 7 are sufficient to determine X_2. The capacitance, resistance or inductance is readily determined knowing the reactance and frequency, (see Section 2.5).

3.3 CIRCUIT DESIGN

The simplified schematic diagram of the RA 79 is shown in Figure 3.3A. The quadrature generator and voltmeter circuits are isolated from the generator input by means of a transformer. This transformer has a separate primary winding to provide isolation and polarity reversal functions. The secondary winding serves two functions; it provides decade steps for adjusting voltage to the quadrature amplifier, and it also provides voltage taps for the voltmeter ranges.

Both the quadrature amplifier and the voltmeter amplifier use transistor circuitry and together they consume less than two watts total power. An integrating amplifier provides the 90° phase shift function of the quadrature generator. The quadrature generator inserts a variable voltage (+90° or -90° phase angle) between the decade transformer tap and the grounded side of the detector. At 1kc the maximum quadrature voltage insertion is 0.01 times the input voltage.



SIMPLIFIED SCHEMATIC DIAGRAM

Fig 3.3A

The voltmeter amplifier is a two-stage, wide-band amplifier circuit. Input limiting is provided to protect the first transistor against severe overload. An adjustable resistor in the feedback loop controls the meter full scale setting. Eight voltmeter ranges plus an "OFF" position (shorted input) are provided. The voltmeter circuit causes minor loading of the decade transformer when it is connected between either input terminal and the output tap.

The quadrature amplifier is an integrating amplifier. It has a high impedance Darlington input stage followed by a single, high gain stage which is followed by an emitter follower output stage. Additional open loop, low frequency gain is provided by positive feedback between the last two stages. The output transistor is protected against accidental external overload by a pair of limiting zener diodes.

The quadrature RANGE switch provides 180° phase reversal of the quadrature voltage by reversal of the input transformer leads. Also, two range multipliers can be selected by this switch. The x0.1 multiplier position connects a 0.4μf capacitor in the feedback loop; the x1 position connects a 0.04μf capacitor.

Position V21 of the INPUT SELECT switch will be used in most applications. This will allow the voltmeter to read the voltage across the external generator. Positions V23 and V31 will cause minor loading of the decade transformer in some cases.

SECTION IV

MAINTENANCE

4.1 VOLTMETER CALIBRATION

Only one adjustment is necessary to calibrate the RA 79 voltmeter. Calibration is accomplished by adjusting a trimmer resistor which is located on the voltmeter printed circuit board. This one adjustment calibrates the voltmeter on all ranges. The calibration procedure is as follows:

1) Remove the dust cover from the RA 79.

2) Connect a generator to the GEN 1 and 2 terminals (see Figure 2.1A).

3) Connect a calibrated voltmeter (1% accuracy) to the GEN 1 and 2 terminals.

4) Set the RA 79 VOLTS switch to 10.

5) Turn the generator ON and adjust its frequency to 1kc.

6) Turn the RA 79 ON and allow a five minute warm-up.

7) Adjust the generator voltage so the calibrated voltmeter reads 10 volts.

8) Adjust the trimmer resistor as shown in Figure 4.1A until the RA 79 meter reads exactly full scale.

9) Turn the RA 79 and the generator OFF and replace the dust cover.

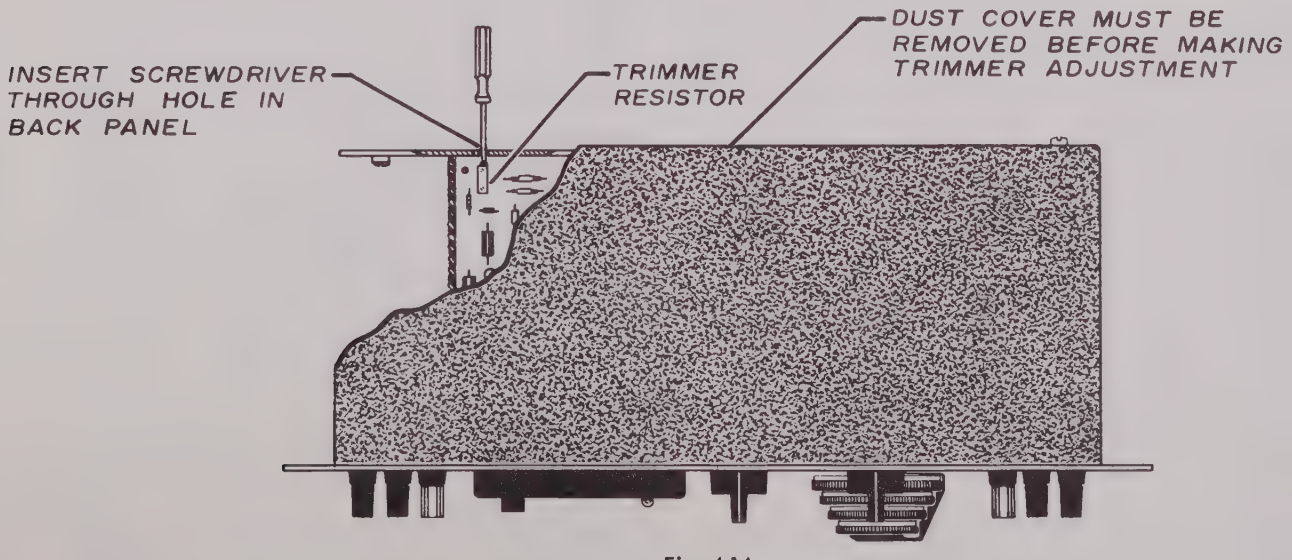
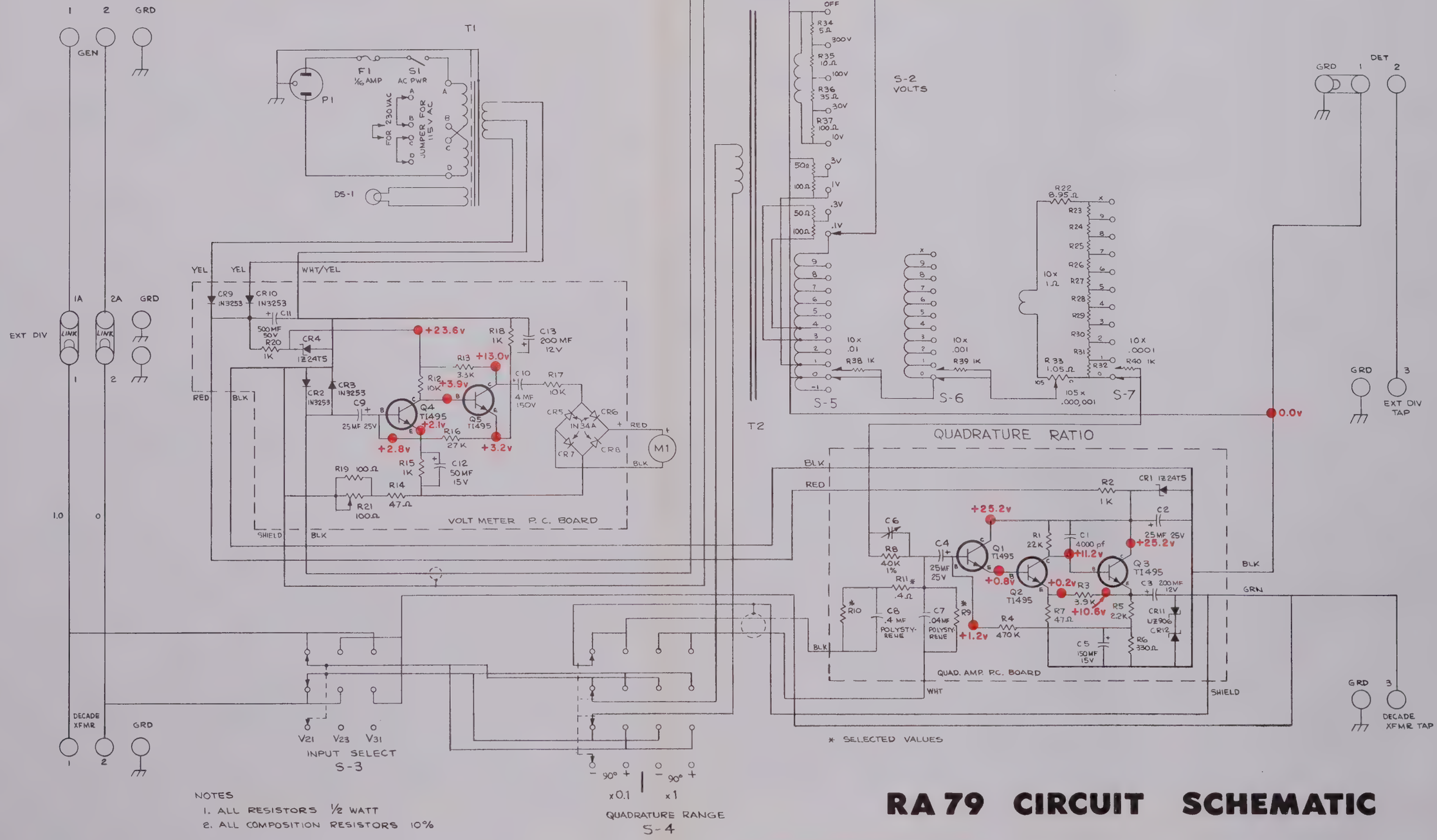

INSERT SCREWDRIVER THROUGH HOLE IN BACK PANEL
TRIMMER RESISTOR
DUST COVER MUST BE REMOVED BEFORE MAKING TRIMMER ADJUSTMENT

Fig 4.1A

4.2 CIRCUIT DIAGRAM AND TEST VOLTAGES

The circuit diagram shown on the opposite page indicates test voltages in red. These voltages are for use in case of equipment failure. Normally any malfunction of the RA 79 will be indicated by a considerable change in one or more of the voltages at these test points.



NOTES
1. ALL RESISTORS ½ WATT
2. ALL COMPOSITION RESISTORS 10%

RA 79 CIRCUIT SCHEMATIC

Voltages indicated are approximate values, and are measured with meter having 10 MEG input inpedance.

SECTION V

PARTS LIST

The following parts list is in alpha-numerical order of the circuit reference designator. Miscellaneous parts are included at the end of the list. Manufacturer of the part is given in a code number according to the Federal Supply Code for Manufacturers; see list of manufacturers below. Parts recommended as spare parts to sustain operation in isolated locations are indicated in the recommended spare parts column.

Parts manufactured by Electro Scientific Industries must be ordered from the factory. When ordering parts from the factory, include the following information:

Model and serial number of the instrument
Electro Scientific Industries part number
Circuit reference designator
Description of part

CODE LIST OF MANUFACTURERS

00884	ELECTRONIC FABRICATORS, INC. New York, New York
01121	ALLEN-BRADLEY CO. Milwaukee, Wis.
01295	TEXAS INSTRUMENTS, INC. Components Division Dallas, Texas
02735	RCA Semiconductor and Materials Division of Radio Corp. of America Sommerville, N. J.
08806	GENERAL ELECTRIC CO., Miniature Lamp Department of Lamp Division of Consumer Products Group Cleveland, Ohio
11837	ELECTRO SCIENTIFIC INDUSTRIES, INC. Portland, Ore.
12969	UNITRODE TRANSISTOR PRODUCTS, INC. Waltham, Mass.

44655	OHMITE MFG. CO. Skokie, Ill.
56289	SPRAGUE ELECTRIC CO. North Adams, Mass.
73586	CIRCLE F MFG. CO. Trenton, N. J.
75915	LITTELFUSE, INC. Des Plaines, Ill.
81483	INTERNATIONAL RECTIFIER CORP., El Segunda, Calif.
84171	ARCO ELECTRONICS, INC. Great Neck, N. Y.
93332	SYLVANIA ELECTRIC PRODUCTS, INC. Semiconductor Products Division Woburn, Mass.
12574	C.G. ELECTRONICS CORP., Albequerque, N. Mex.

Ckt Ref	Description	Mfr	ESI Part No.	Qty Used	Recm SP
A_1	Ass'y Dekatran	11837	8949	1	
C_1	Cap., Fxd, Mica, 4000pf 1%, Mfr PN D25809	84171	1943	1	
C_2	Cap., Fxd, 25µf, 25v, Mfr PN D25809	56289	1941	2	
C_3	Cap., Fxd, 200µf, 12v, Mfr PN TE-1137	56289	1940	3	
C_4	Same as C_2				
C_5	Cap., Fxd, Elect., 150µf, 15vdc, Mfr PN TE 1163	56289	15837	1	
C_6	Cap., variable, Mfr PN 423, 7-100pf	84171	1939	1	

Ckt Ref	Description	Mfr	ESI Part No.	Qty Used	Recm SP
C_7	Cap., Fxd, Polystrene, .04μf -3/4% +1/4 500vc, Mfr PN PHG	00884	1411	1	
C_8	Cap., Fxd, Polystrene, 0.4μf -3/4% +1/4 500vc, Mfr PN	00884	1415	1	
C_9	Same as C_3				
C_{10}	Cap., Fxd, Elect., 4μf, 150v, Mfr PN TE-1503	56289	1912	1	
C_{11}	Cap., Fxd, Elect., 500μf, 50vdc, Mfr PN TVA 1513	56289	1942	1	
C_{12}	Cap., Fxd, Elect., 50μf, 15v, Mfr PN TE-1160	56289	15836	1	
C_{13}	Same as C_3				
CR_1	Diode, Zener, Mfr PN 1Z24T5	81483	8929	2	
CR_2	Diode, Silicon, Mfr PN IN3253	02735	9152	4	
CR_3	Same as CR_2				
CR_4	Same as CR_1				
CR_5	Diode, Germanium, Mfr PN IN34A	93332	15677	4	
CR_6	Same as CR_5				
CR_7	Same as CR_5				
CR_8	Same as CR_5				
CR_9	Same as CR_2				

Ckt Ref	Description	Mfr	ESI Part No.	Qty Used	Recm SP
CR_{10}	Same as CR_2				
CR_{11}	Diode, Zener, 6.8v, 3w, Mfr PN UZ906	12969	8963	2	
CR_{12}	Same as CR_{11}				
DS_1	Lamp #47	08806	1800	1	
F_1	Fuse Cartridge 1/16 amp	75915	8952	1	
M_1	Meter	11837	8925	1	
Q_{1-5}	Transistor, Mfr PN T1495	01295	8928	5	
R_1	Res, Fxd, Comp, 22k 10%, 1/2w, Mfr PN EB-2321	01121	2018	1	
R_2	Res, Fxd, Comp, 3.9k 10%, 1/2w, Mfr PN EB-1021	01121	1969	4	
R_3	Res, Fxd, Comp, 3.9k 10%, 1/2w, Mfr PN EB-3921	01121	2027	1	
R_4	Res, Fxd, Comp, 470k 10%, 1/2w, Mfr PN EB-4741	01121	2030	1	
R_5	Res, Fxd, Comp, 2.2k 10%, 1/2w, Mfr PN EB-2221	01121	1957	1	
R_6	Res, Fxd, Comp, 330Ω 10%, 1/2w, Mfr PN EB-3311	01121	2025	1	
R_7	Res, Fxd, Comp, 47Ω 10%, 1/2w, Mfr PN EB-4701	01121	2024	2	
R_8	Res, Fxd, Deposited Carbon, 40k 1%, 1/2w	44655	2029		

Ckt Ref	Description	Mfr	ESI Part No.	Qty Used	Recm SP
R_9	Res, Fxd, Comp, 8.2 meg 10%, 1/2w, Mfr PN EB-8251	01121	2028	1	
R_{10}	Res, Fxd, Comp, 10 meg 10%, 1/2w Mfr PN EB-1061	01121	2031	1	
R_{11}	Res, Fxd, WW, 0.4Ω	11837	8948	1	
R_{12}	Res, Fxd, Comp, 10k 10%, 1/2w, Mfr PN EB-1031	01121	1961	2	
R_{13}	Res, Fxd, Comp, 3.3k 10%, 1/2w, Mfr PN EB-3321	01121	1970	1	
R_{14}	Same as R_7				
R_{15}	Same as R_2				
R_{16}	Res, Fxd, Comp, 27k 10%, 1/2w, Mfr PN EB-2731	01121	1962	1	
R_{17}	Same as R_{12}				
R_{18}	Same as R_2				
R_{19}	Res, Fxd, Comp, 100Ω 10%, 1/2w, Mfr PN EB-1011	01121	1977	1	
R_{20}	Same as R_2				
R_{21}	Trimmer, Bourns EZ Trim 100Ω, Mfr PN 3067S-1-101	12574	8930	1	
R_{22}	Res, Fxd, WW, 8.95Ω, Part of Ass'y A_1	11837	8955	1	
R_{23}	Res, Fxd, WW, 1Ω, Part of Ass'y A_1	11837	8956	10	

Ckt Ref	Description	Mfr	ESI Part No.	Qty Used	Recm SP
$R_{24 - 32}$	Same as R_{23}				
R_{33}	Potentiometer, 1.05Ω, Part of Ass'y A_1*		8949	1	
R_{34}	Res, Fxd, WW, 5Ω	11837	8960	1	
R_{35}	Res, Fxd, WW, 10Ω	11837	8959	1	
R_{36}	Res, Fxd, WW, 35Ω	11837	8958	1	
R_{37}	Res, Fxd, WW, 100Ω	11837	8957	1	
$R_{38 - 40}$	Res, Fxd, Comp, 1k 10%, 1/2w, Mfr PN EB-1021, Part of Ass'y A_1*	01121	8949	3	
S_1	Toggle Switch SPDT, Mfr PN L62D	73586	3963	1	
S_2	Switch, Rotary, 2 section, 9 positions	11837	8946	1	
S_3	Switch, Rotary, 1 section, 3 positions	11837	8947	1	
S_4	Switch, Rotary, 2 section, 4 position	11837	8945	1	
	MISCELLANEOUS				
	Cap, Binding Post, Black	11837	1170	12	5
	Cap, Binding Post, Gold	11837	1172	7	3
	Connecting link	11837	3247	3	2
	Post, Binding	11837	1393	19	

* Replacement recommended at factory facility only

Ckt Ref	Description	Mfr	ESI Part No.	Qty Used	Recm SP
	Dial, -1 thru 9	11837	8927	1	
	Dial, 0 - X	11837	4763	1	
	Dial, 0 - X	11837	4764	1	
	Dial, 0 - V 105 Divisions, 315°	11837	4967	1	
	Knob, Bar	11837	1266	3	2

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BRIDGES
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ACCESSORIES

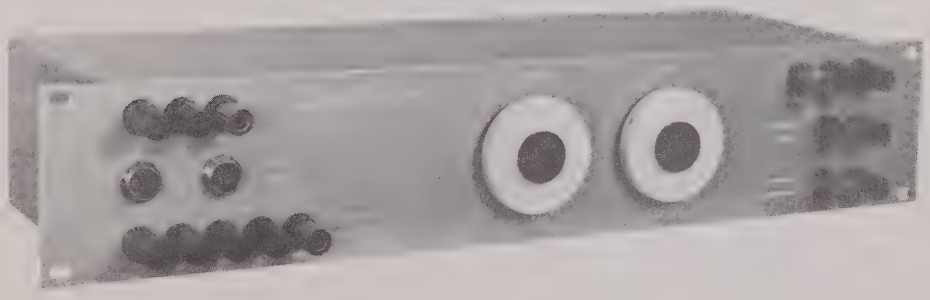
OCTOBER 1965
REPLACES NOVEMBER 1964

MODEL

874

Instruction Manual

PHASE COMPENSATOR



SERIAL NUMBER:_____

PART NUMBER: 9065

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The following table lists the most recent revision of each page at the present date of printing:

PAGE	DATE
Title	10/65
A	10/65
i	10/65
1-1 thru 1-2	10/65
2-1 thru 2-4	10/65
3-1 thru 3-2	10/65
4-1	10/65

TABLE OF CONTENTS

I INTRODUCTION

1.1 DESCRIPTION 1 - 1

1.2 SPECIFICATIONS 1 - 2

1.3 APPLICATIONS 1 - 2

II OPERATING INSTRUCTIONS

2.1 GENERATOR-DETECTOR CONNECTIONS 2 - 1

2.2 STANDARD DECADE TRANSFORMER CONNECTIONS 2 - 1

2.3 MEASUREMENT CONNECTIONS 2 - 2

2.4 OPERATING PROCEDURE 2 - 3

III THEORY

3.1 TRANSFORMER COMPARISON 3 - 1

3.2 RESISTIVE DIVIDER COMPARISON 3 - 1

3.3 SCHEMATIC DIAGRAM 3 - 2

IV REPLACEMENT PARTS 4 - 1

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DEKAPACITOR® Decade Capacitor
DEKAVIDER® Decade Voltage Divider
KELVIN KLIPS® Four-terminal Clips
KELVIN KLAMPS® Four-terminal Clamps
PORTAMETRIC® Portable Measuring Instrument
PVB® Potentiometric Voltmeter Bridge

Application for registration has been filed for the following:

DEKATRAN Decade Transformer

I INTRODUCTION

1.1 DESCRIPTION

The Model 874 Phase Compensator is a device that compensates for the phase difference between the outputs of voltage dividers. With the phase compensation that is possible with this instrument, transformer and resistive dividers can be compared with an accuracy of better than one part per million.

The instrument is basically a special modified differential capacitor which is connected in the measurement circuit as shown in Figure 1-1.

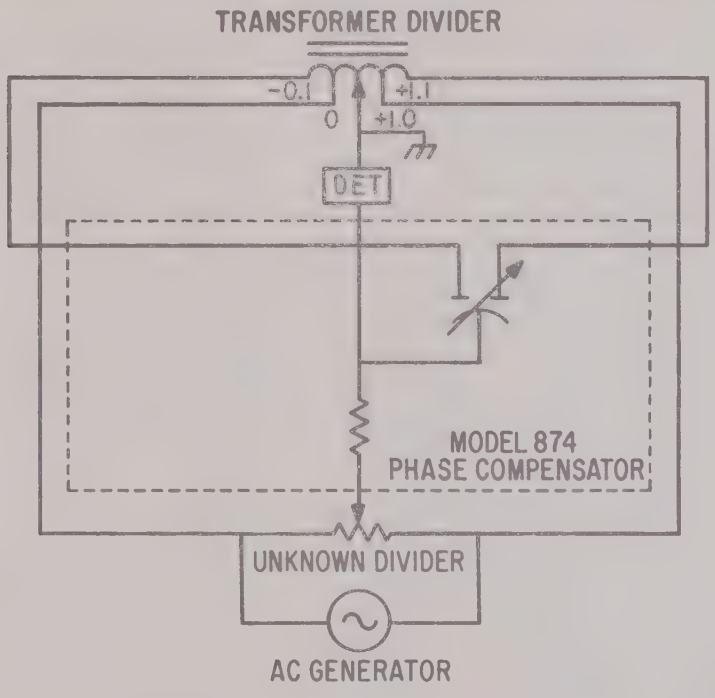

Figure 1-1 Phase Compensated Measurement Circuit

The differential capacitor provides a variable amplitude quadrature voltage; a voltage that is shifted 90° in phase from the input voltage to the dividers. When the differential capacitor is adjusted properly, the difference between the quadrature components of the voltage divider outputs is cancelled out. When the voltage divider ratios are adjusted properly, the in-phase component of the voltage divider outputs are equal. If both the quadrature and in-phase voltages are balanced, a sharp detector null results and very small changes in either the quadrature or in-phase balances can be seen.

1.2 SPECIFICATIONS

The minimum quadrature range with respect to full scale input is approximately as follows for any voltage divider setting (s):

Coarse Dial:	$+(1.1-S) \times 600 \times f_{kc}$ ppm
	$-(0.1-S) \times 600 \times f_{kc}$ ppm
Fine Dial:	$+(1.1-S) \times 15 \times f_{kc}$ ppm
	$-(0.1-S) \times 15 \times f_{kc}$ ppm
Maximum Input Voltage:	350 volts rms

1.3 APPLICATIONS

Generally the Model 874 is used as a part of a system for making ac ratio measurements. The quadrature output of the instrument is connected in series with the tap voltage of a standard decade transformer. The in-phase component of a voltage ratio can then be determined from the dial settings of the decade transformer since the Model 874 cancels the out-of-phase component. Figure 1-1 illustrates a typical system which is used to calibrate a voltage divider.

The Model 874 may be used with either resistive or transformer voltage dividers as unknown dividers.

II OPERATING INSTRUCTIONS

In most applications, the Model 874 Phase Compensator is combined with a generator-detector and a standard decade transformer to produce a voltage ratio calibration system. The instructions for connecting the measurement system should be carefully followed before making Voltage Divider Calibrations or Impedance Comparisons.

2.1 GENERATOR-DETECTOR CONNECTIONS

A rack-mounted generator-detector such as the ESI Model 861A can be mounted above the Model 874 and connected by links as shown in Figure 2-1. The shield covers over these links (see Figure 2-2) minimize the effects of stray electrical signals.

When using generator-detectors that are not mounted directly above the Model 874, it is important to shield the detector input. The shielding of the generator terminals is optional.

If the detector is internally grounded, there should be no link between the AC DET 1 terminal and the GRD terminal. (The 861A detector is internally grounded.)

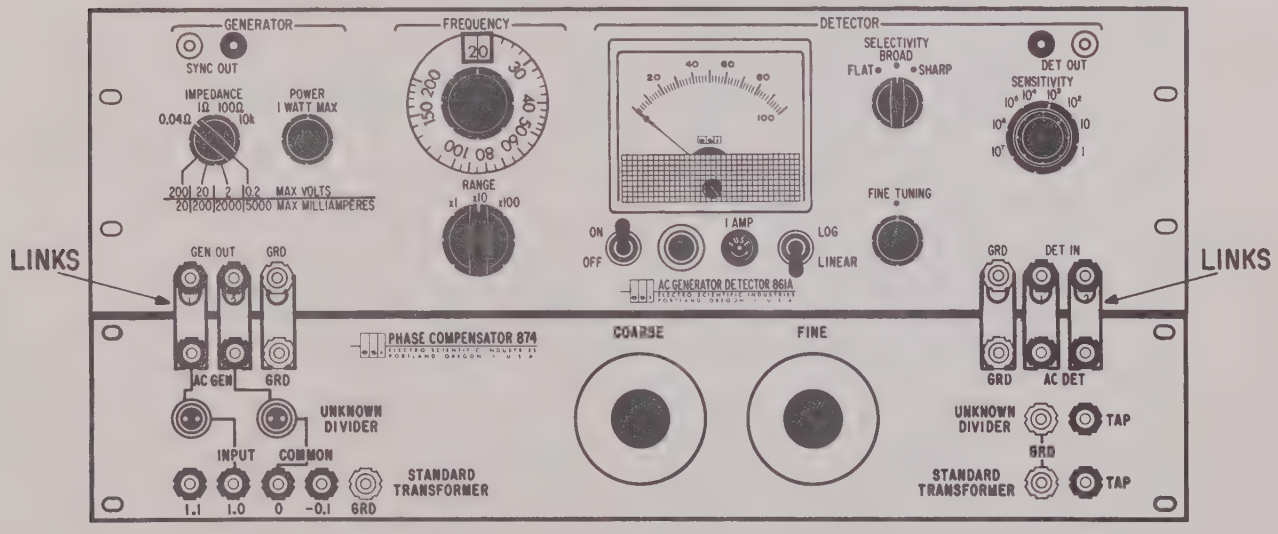

Figure 2-1 Generator-Detector Connections

2.2 STANDARD DECADE TRANSFORMER CONNECTIONS

Normally a standard decade transformer such as the ESI Model DT 72A will be rack-mounted below the Model 874. For most applications the decade transformer is connected as shown in Figure 2-2. It is not necessary to shield the leads to the standard transformer. If the decade transformer is not a DT 72A and does not have 1.1 and -0.1 taps, but has taps labeled HI and LO, INPUT and COMMON, or some similar nomenclature, it may still be used with the Model 874, but phase compensation near the end points of the standard transformer settings may

be insufficient. If such a transformer is used; connect the Model 874 STANDARD TRANSFORMER 1.1 terminal to the 1.0 terminal, connect the 0 terminal to the -0.1 terminal, and connect these terminal pairs to the input terminals of the standard transformer.

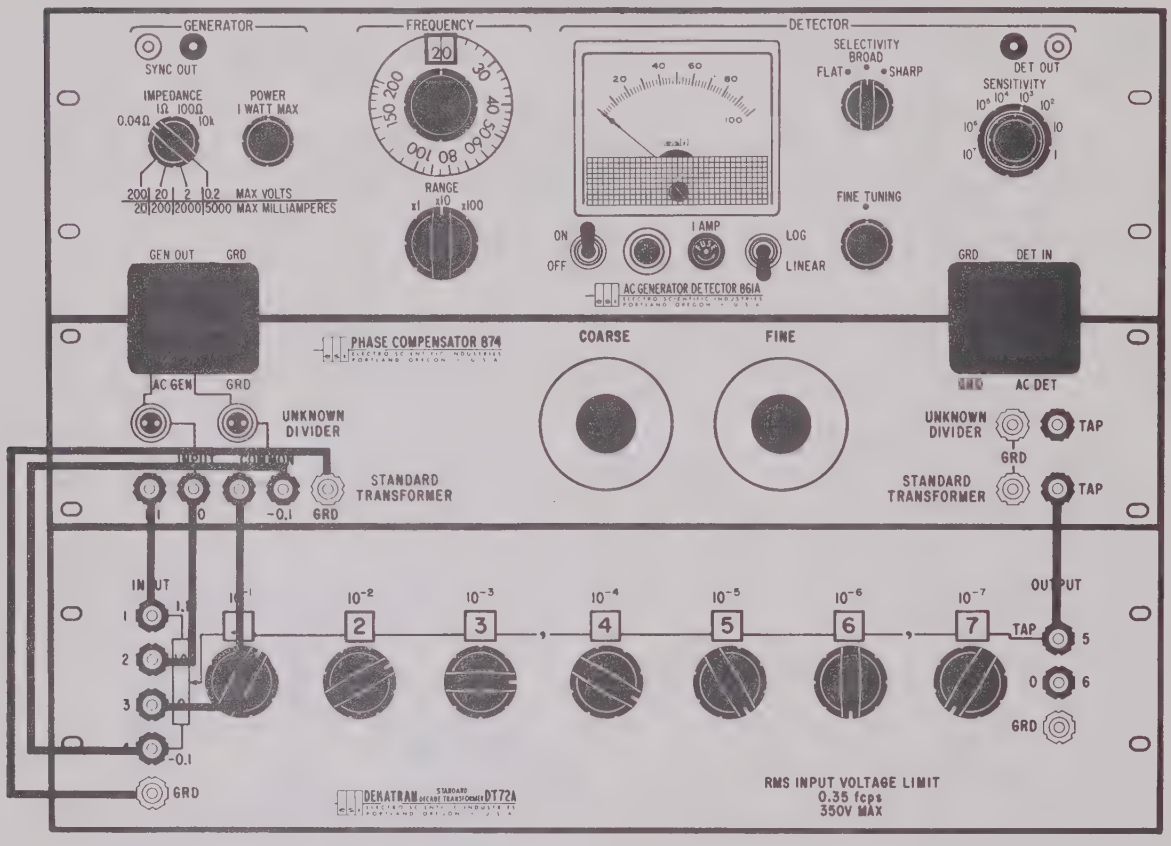

Figure 2-2 Standard Transformer Connections

2.3 MEASUREMENT CONNECTIONS

For most measurement applications, the Model 874 Phase Compensator is connected to an unknown divider with four-terminal connections which reduce or eliminate lead compensation problems. The UNKNOWN DIVIDER jacks are especially adapted for KELVIN KLIPS®, which are four-terminal clip-type connectors. Other four-terminal devices, of course, may be used.

The taps of the standard transformer and of the unknown divider are connected to appropriately labeled terminals on the right-hand side of the instrument.

2.4 OPERATING PROCEDURE

The typical measurement made with a system using the Model 874 Phase Compensator involves two voltage dividers, at least one of which, the standard divider, is a transformer. The following is a description of a typical measurement procedure:

1. Connect generator, detector, and standard transformer to the Model 874 as described in Paragraphs 2.1 and 2.2.

2. Connect unknown divider to Model 874 with Kelvin Klips as shown in Figure 2-3.

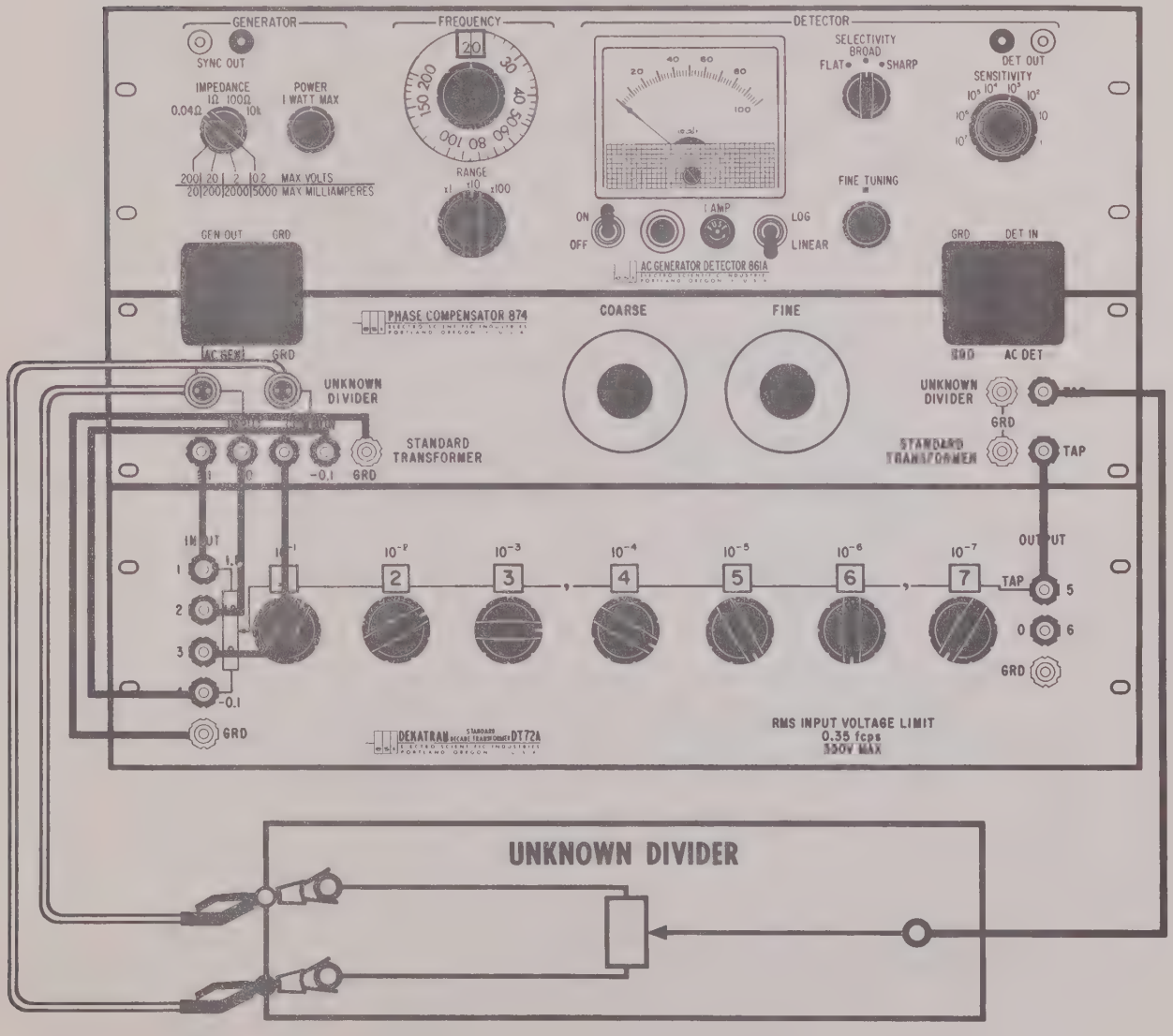

Figure 2-3 Unknown Divider Connections

3. Turn on generator and detector. Allow time for warm-up if necessary.

4. Apply generator power and set detector to a level that is less than full scale.

5. Adjust standard divider for lowest detector indication, increasing detector sensitivity as required. At some point in this step, the detector will be at its minimum indication, and the sensitivity will be still too low for highest accuracy, but if a higher-sensitivity setting is used, the indication will be off scale.

6. Adjust COARSE control for lowest detector indication.

7. Increase detector sensitivity as required, and adjust standard divider and FINE control alternately until the lowest possible detector indication is reached with the greatest possible detector sensitivity.

8. At this time, the two dividers are as equal as the resolution of the standard transformer and the sensitivity of the detector will permit.

III THEORY

The Model 874 Phase Compensator is a capacitor which draws current through a resistance. It can be used to correct for and measure phase differences when comparing dividers.

3.1 TRANSFORMER COMPARISON

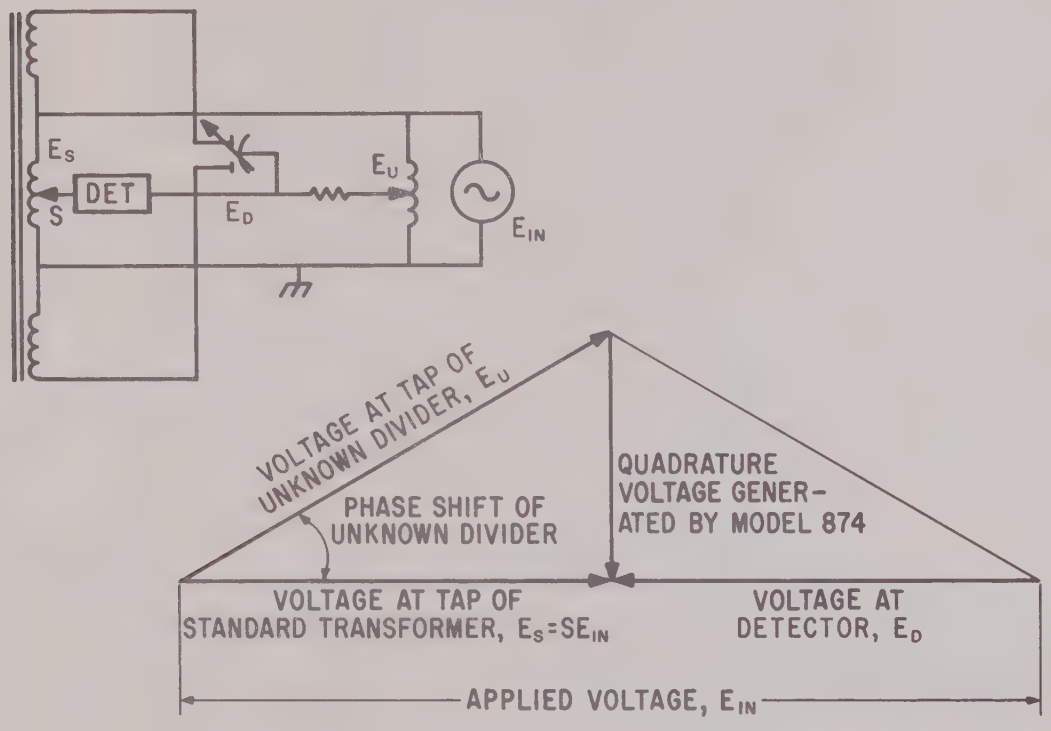

Figure 3-1 Angle Correcting Circuit

The resistor and capacitor are connected into the circuit to change the detector voltage so that the voltage along the resistor will be 90° out of phase with the applied voltage. This results in the same setting of the standard divider that would have been obtained with a phase-sensitive detector.

3.2 RESISTIVE DIVIDER COMPARISON

The differential capacitor serves the additional function of balancing out the divider capacitance. The major part of the resistive divider phase shift is caused by capacitance from the lower decades to case, which appears as a capacitive load to case. When the differential capacitor is set so that it and the load capacitance combine to form a capacitive divider with the same setting as the resistive divider, not only is the

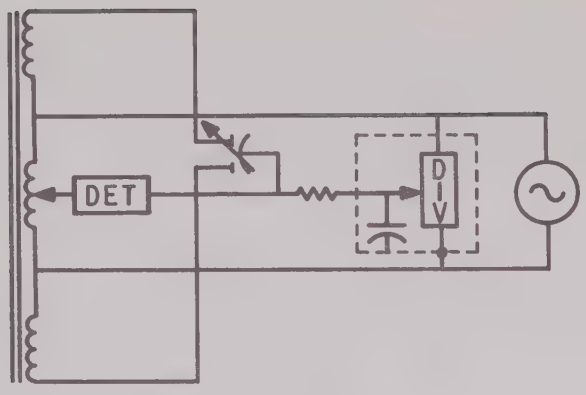

Figure 3-2 Divider Comparison

phase corrected, but in effect, the capacitive load is removed. Thus the ac divider linearity deviations are much more nearly equal to the dc values.

3.3 SCHEMATIC DIAGRAM

Figure 3-3 illustrates schematically the circuit of the Model 874 Phase Compensator.

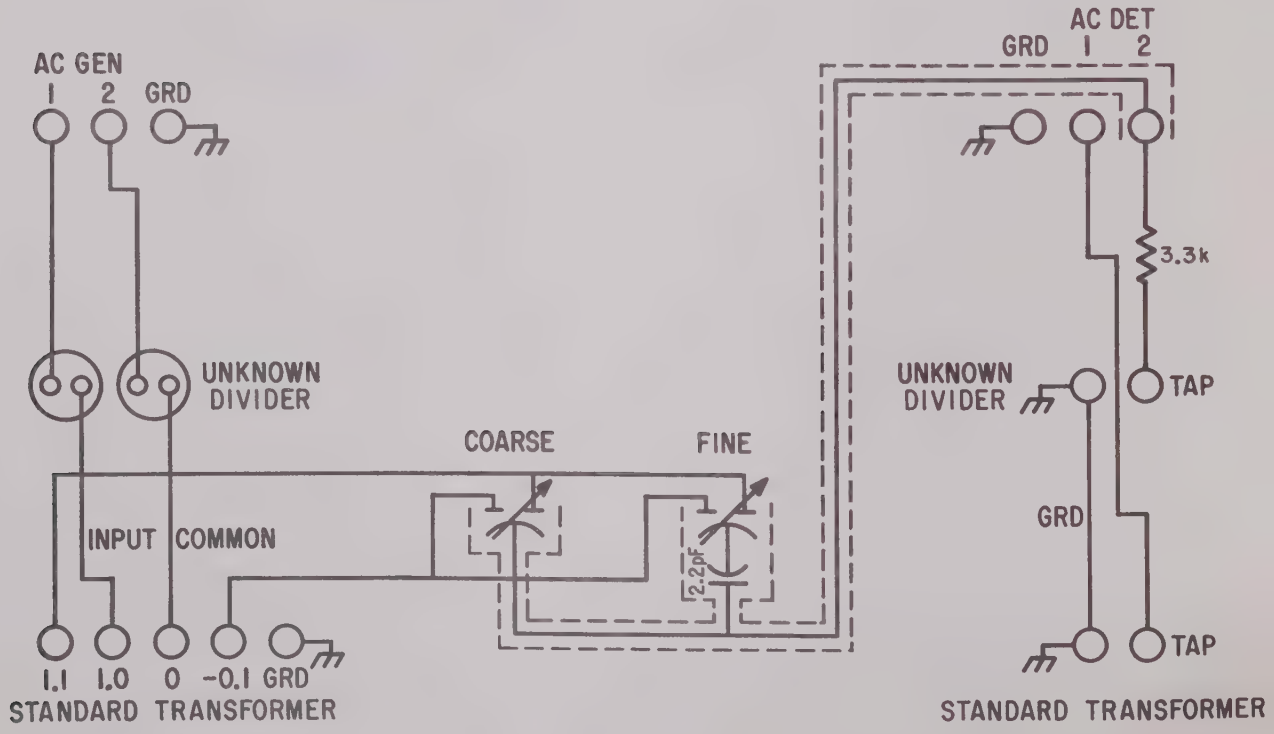

Figure 3-3 Schematic Diagram

IV REPLACEMENT PARTS

The following parts list is in alphabetical order of the description of the part. It is recommended that parts not on this list be replaced or repaired at the factory. When ordering replacement parts, please include the following information:

Model and serial number of the instrument

ESI part number

Description of part

DESCRIPTION	PART NO.	QTY USED
Ball Drive	9061	2
Base, Cast	9057	2
Binding Post	1393	15
Binding Post Cap, Black, Insulating	1170	10
Binding Post Cap, Gold Plated	1172	5
Bracket, Dust Cover Securing	9055	2
Bushing, Delrin, Ball Drive Shaft	9053	2
Bushing, Dial	5289	2
Shield, Round	4836	2
Capacitor, Fixed, 2.2 pF	9063	1
Capacitor, Variable	9062	2
Connector, Panel Mount, Female	8378	2
Flexible Coupling, Insulating	8053	2
Dial Assy	9056	2
Dust Cover	7905	1
Gromets, Lead Insulating	1601	6
Insulating Washer, Binding Post	8823	10
Panel, Front	9060	1
Plate, Cap. Mounting	9059	2
Resistor, 3.3kΩ, Composition	1970	1
Shaft, Coupling	9054	2
Shoulder Washer, Capacitor Mounting	3058	2
Spacer Disk, Fiber	9064	4
Stop Plate, Ball Drive	9058	2
Test Leads, KELVIN KLIPS®	8309	1 pr
Washer, Nylon, Capacitor Mounting	73008	2

SEPTEMBER 1966

ESI® INSTRUCTION MANUAL CHANGES

Model 874 Phase Compensator

Instruction Manual dated October 1965

Section III, first paragraph: Change second sentence from "It can be used to correct for and measure phase differences when comparing dividers." to "It can be used to correct for phase differences when comparing dividers."

Part No. 9065-2

MP MASTER
MA30781